Lake Powell Pipeline

Draft Study Report 4
Geology and Soil Resources

March 2011

Geology and Soils Study Report
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Executive Summary

ES-1 Introduction

This study report describes the results and findings of an analysis to evaluate geology and soil resources impacts along the proposed alternative alignments of the Lake Powell Pipeline Project (LPP Project), No Lake Powell Water Alternative, and No Action Alternative. The purpose of the analysis, as defined in the 2008 Geology and Soils Study Plan prepared for the Federal Energy Regulatory Commission (Commission), was to identify potential impacts of geologic and soil conditions on the LPP Project during construction and operation, document the potential influence of soil and geologic conditions on LPP Project features, and identify measures to mitigate impacts of the geology and soils conditions.

ES-2 Methodology

The analysis of impacts on geology and soil resources follows methodology identified and described in the Preliminary Application Document, Scoping Document No. 1 and the Geology and Soil Study Plan filed with the Commission.

ES-3 Key Results of the Geology and Soil Resources Impact Analyses

Significance criteria were established based on fault movement, seismic activity, unstable slopes, expandable, collapsible, or subsiding soils or rocks, geologic hazards to human health and safety, important structures and mineral resources, and borrow and spill. The following sections summarize the key results of the geology and soil resources impact analyses.

ES-3.1 South Alternative

No significant impacts associated with the impact topics are expected to occur during construction and operation of the South Alternative. Fault movement along the alignment is expected to be below 75 mm during the design life of the LPP Project, the alignment is not within a zone of high projected Peak Ground Acceleration (PGA), construction and operation of the pipeline and associated features would not cause slope failures that could result in injury to humans, damage to major human structures, or damage to the environment, geologic hazards would not cause deformation or failure of foundation conditions sufficient to cause pipeline rupture or failure of associated pipeline features, the impacts of geologic hazards along the alignment would not result in human injury or death, present a serious risk to human health, or cause major damage to structures, and borrow and spoil associated with the alternative will not cause new and substantial disturbance of land or cause substantial changes in runoff patterns, turbid runoff that would discharge to rivers, streams, or lakes, or create unstable slope conditions.

Precautions may be necessary during construction and operation to preclude significant impacts, such as conducting site stabilization measures, trench shoring or sloping, removal of rock and soil at risk of failure prior to heavy earthwork or blasting, using lower-energy blasting methods, and other standard construction safety practices. In addition, special design considerations may be necessary, such as using appropriate seismic design standards for pipelines and associated facilities, and over excavating and placing additional bedding when constructing in expandable, collapsible, or subsiding soils or rocks.

ES-3.2 Existing Highway Alternative

Impacts would be the same as for the South Alternative. No significant impacts would occur during construction and operation.

ES-3.3 Southeast Corner Alternative

Impacts would be the same as for the South Alternative. No significant impacts would occur during construction and operation.

ES-3.4 Cedar Valley Pipeline Alternative

No significant impacts associated with the impact topics are expected to occur during construction and operation. Precautions may be necessary during construction and operation to preclude significant impacts, such as conducting site stabilization measures, trench shoring or sloping, removal of rock and soil at risk of failure prior to heavy earthwork or blasting, using lower-energy blasting methods, and other standard construction safety practices. In addition, special design considerations may be necessary, such as using appropriate seismic design standards for pipelines and associated facilities, and over excavating and placing additional bedding when constructing in expandable, collapsible, or subsiding soils or rocks. Reduction of pumping of groundwater in the Cedar Valley would help to reduce the rate of land subsidence associated with over pumping of the aquifer, and may cause subsidence to halt, which would be a positive impact.

ES-3.5 No Lake Powell Water Alternative

Over pumping of groundwater in the Cedar Valley would continue to deplete the aquifer, which would result in continuation of land subsidence. The effect on land users could be significant if subsidence changes drainage patterns. Also, soil fissures caused by land subsidence already allow direct inflow of raw surface water into the ground and may provide a conduit for surface water to flow unfiltered into the aquifer. If this trend continues due to over pumping, it could have a significant impact on groundwater quality. No impacts are expected to the other impact topics.

ES-3.6 No Action Alternative

Impacts would be the same as for the No Lake Powell Water Alternative.

Chapter 1
Introduction

1.1 Introduction

This chapter presents a summary description of the alternatives studied for the Lake Powell Pipeline (LPP) project, located in north central Arizona and southwest Utah (Figure 1-1) and identifies the issues and impact topics for the Geology and Soil Resources Study Report. The alternatives studied and analyzed include different alignments for pipelines and penstocks and transmission lines, a no Lake Powell water alternative, and the No Action alternative. The pipelines would convey water under pressure and connect to the penstocks, which would convey the water to a series of hydroelectric power generating facilities. The action alternatives would each deliver 86,249 acre-feet of water annually for municipal and industrial (M&I) use in the three southwest Utah water conservancy district service areas. Washington County Water Conservancy District (WCWCD) would receive 69,000 acre-feet, Kane County Water Conservancy District (KCWCD) would receive 4,000 acre-feet and Central Iron County Water Conservancy District (CICWCD) could receive up to 13,249 acre-feet each year.

1.2 Summary Description of Alignment Alternatives

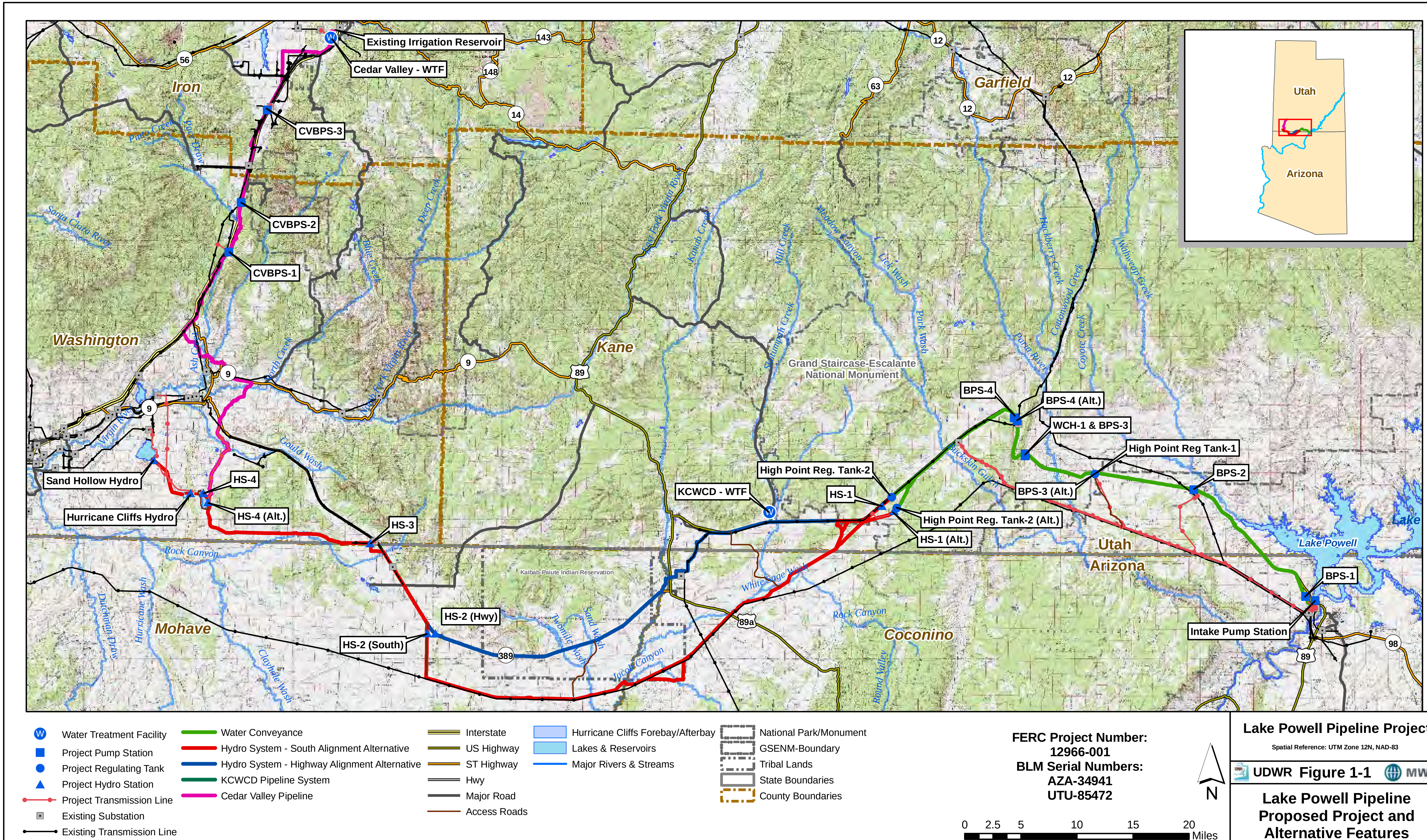
Three primary pipeline and penstock alignment alternatives are described in this section along with the electrical power transmission line alternatives. The pipeline and penstock alignment alternatives share common segments between the intake at Lake Powell and delivery at Sand Hollow Reservoir, and they are spatially different in the area through and around the Kaibab-Paiute Indian Reservation. The South Alternative extends south around the Kaibab-Paiute Indian Reservation. The Existing Highway Alternative follows an Arizona state highway through the Kaibab-Paiute Indian Reservation. The Southeast Corner Alternative follows the Navajo-McCullough Transmission Line corridor through the southeast corner of the Kaibab-Paiute Indian Reservation. The transmission line alignment alternatives are common to all the pipeline and penstock alignment alternatives. Figure 1-1 shows the overall proposed project and alternative features from Lake Powell near Page, Arizona to Sand Hollow and Cedar Valley, Utah.

1.2.1 South Alternative

The South Alternative consists of five systems: Intake, Water Conveyance, Hydro, Kane County Pipeline, and Cedar Valley Pipeline.

The **Intake System** would pump Lake Powell water via submerged horizontal tunnels and vertical shafts into the LPP. The intake pump station would be constructed and operated adjacent to the west side of Lake Powell approximately 2,000 feet northwest of Glen Canyon Dam in Coconino County, Arizona (Figure 1-2). The pump station enclosure would house vertical turbine pumps with electric motors, electrical controls, and other equipment at a ground level elevation of 3,745 feet mean sea level (MSL).

The **Water Conveyance System** would convey the Lake Powell water from the Intake System for about 51 miles through a buried 69-inch diameter pipeline parallel with U.S. 89 in Coconino County, Arizona and Kane County, Utah to a buried regulating tank (High Point Regulating Tank-2) on the south side of U.S. 89 at ground level elevation 5,695 feet MSL, which is the LPP project topographic high point


Existing Irrigation Reservoir
Cedar Valley - WTF
CVBPS-3
CVBPS-2
CVBPS-1
Iron
Garfield
Washington
Kane
Mohave
Coconino
Utah
Arizona
Grand Staircase-Escalante National Monument
Kaibab-Paiute Indian Reservation
Sand Hollow Hydro
Hurricane Cliffs Hydro
HS-4
HS-4 (Alt.)
HS-3
HS-2 (Hwy)
HS-2 (South)
KCWCD - WTF
High Point Reg. Tank-2
HS-1
HS-1 (Alt.)
High Point Reg. Tank-2 (Alt.)
BPS-4
BPS-4 (Alt.)
WCH-1 & BPS-3
High Point Reg Tank-1
BPS-3 (Alt.)
BPS-2
BPS-1
Intake Pump Station
Lake Powell
Lake
Santa Clara River
Pinto Creek
Virgin River
Ash Creek
North Creek
Gould Wash
Rock Canyon
Deep Creek
Blue Creek
Kanab Creek
Mill Creek
Meadow Canyon
Park Wash
Paria River
Cottonwood Creek
Coyote Creek
Wahweap Creek
Hackberry Creek
Buckskin Gulch
White Sage Wash
Jacob Canyon
Sand Wash
Twomile Wash
Clayhole Wash
Hurricane Wash
Dutchman Draw
Round Valley
56
143
148
14
12
63
9
89
89a
389
98
Utah
Arizona
Water Treatment Facility
Project Pump Station
Project Regulating Tank
Project Hydro Station
Project Transmission Line
Existing Substation
Existing Transmission Line
Water Conveyance
Hydro System - South Alignment Alternative
Hydro System - Highway Alignment Alternative
KCWCD Pipeline System
Cedar Valley Pipeline
Interstate
US Highway
ST Highway
Hwy
Major Road
Access Roads
Hurricane Cliffs Forebay/Afterbay
Lakes & Reservoirs
Major Rivers & Streams
National Park/Monument
GSENM-Boundary
Tribal Lands
State Boundaries
County Boundaries
FERC Project Number:
12966-001
BLM Serial Numbers:
AZA-34941
UTU-85472
0 2.5 5 10 15 20 Miles
N
Lake Powell Pipeline Project
Spatial Reference: UTM Zone 12N, NAD-83
UDWR
Figure 1-1
MWH
Lake Powell Pipeline Proposed Project and Alternative Features

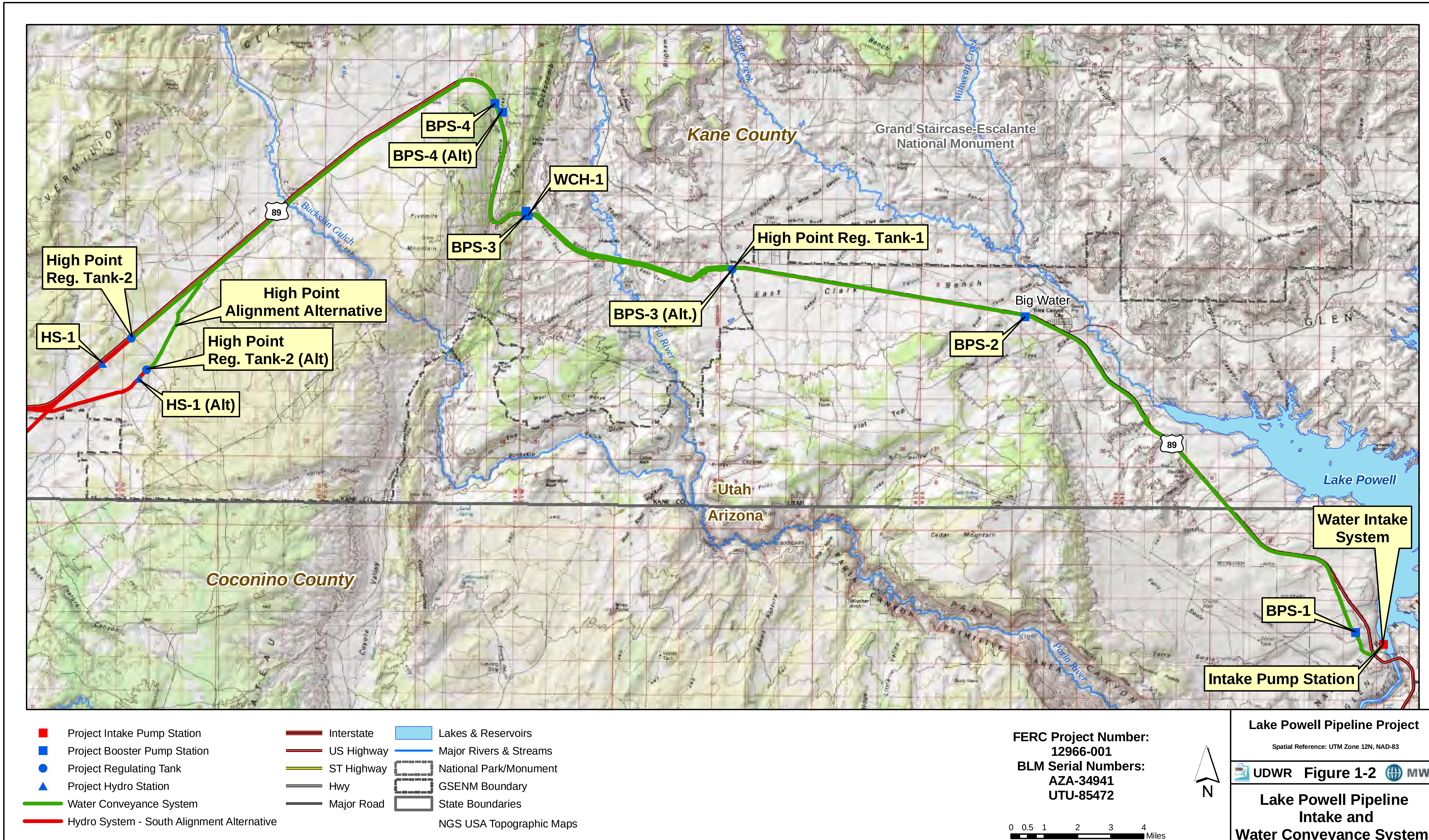


Figure 1-2

Lake Powell Pipeline
Intake and
Water Conveyance Systems

(Figure 1-2). The pipeline would be sited within a utility corridor established by Congress in 1998 which extends 500 feet south and 240 feet north of the U.S. 89 centerline on public land administered by the Bureau of Land Management (BLM) (U.S. Congress 1998). Four booster pump stations (BPS) located along the pipeline would pump the water under pressure to the high point regulating tank. Each BPS would house vertical turbine pumps with electric motors, electrical controls, and other equipment. Additionally, each BPS site would have a substation, buried forebay tank and a surface emergency overflow detention basin. BPS-1 would be sited within the Glen Canyon National Recreation Area adjacent to an existing Arizona Department of Transportation maintenance facility located west of U.S. 89. BPS-2 would be sited on land administered by the Utah School and Institutional Trust Lands Administration (SITLA) near the town of Big Water, Utah on the south side of U.S. 89. BPS-3 and an in-line hydro station (WCH-1) would be sited at the east side of the Cockscomb geologic feature in the Grand Staircase-Escalante National Monument (GSENM) within the Congressionally-designated utility corridor. BPS-3 (Alt) is an alternative location for BPS-3 on land administered by the BLM Kanab Field Office near the east boundary of the GSENM on the south side of U.S. 89 within the Congressionally-designated utility corridor. Incorporation of BPS-3 (Alt.) into the LPP project would replace BPS-3 and WCH-1 at the east side of the Cockscomb geologic feature. BPS-4 would be sited on the west side of U.S. 89 and within the Congressionally-designated utility corridor in the GSENM on the west side of the Cockscomb geologic feature.

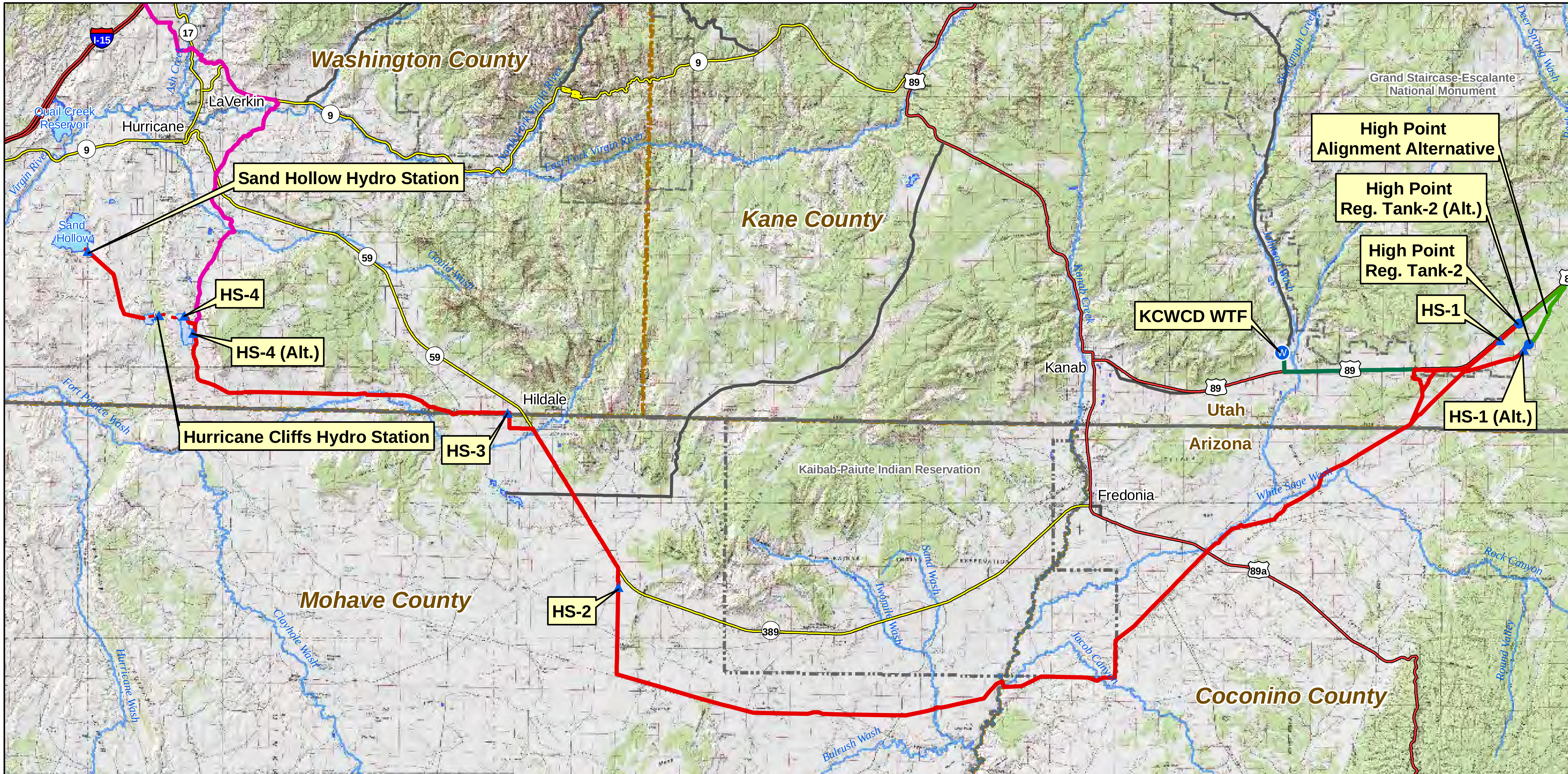
The High Point Alignment Alternative would diverge south from U.S. 89 parallel to the K4020 road and continue outside of the Congressionally-designated utility corridor to a buried regulating tank (High Point Regulating Tank-2 (Alt.) at ground level elevation 5,630 feet MSL, which would be the topographic high point of the LPP project along this alignment alternative (Figure 1-2). The High Point Alignment Alternative would include BPS-4 (Alt.) on private land east of U.S. 89 and west of the Cockscomb geologic feature (Figure 1-2). Incorporation of the High Point Alignment Alternative and BPS-4 (Alt.) into the LPP project would replace the High Point Regulation Tank-2 along U.S. 89, the associated buried pipeline and BPS-4 west of U.S. 89.

A rock formation avoidance alignment option would be included immediately north of Blue Pool Wash along U.S. 89 in Utah. Under this alignment option, the pipeline would cross to the north side of U.S. 89 for about 400 feet and then return to the south side of U.S. 89. This alignment option would avoid tunneling under the rock formation on the south side of U.S. 89 near Blue Pool Wash.

A North Pipeline Alignment option is located parallel to the north side of U.S. 89 for about 6 miles from the east boundary of the GSENM to the east side of the Cockscomb geological feature.

The **Hydro System** would convey the Lake Powell water from High Point Regulating Tank-2 at the high point at ground level elevation 5,695 feet MSL for about 87 miles through a buried 69-inch diameter penstock in Kane and Washington counties, Utah and Coconino and Mohave counties, Arizona to Sand Hollow Reservoir near St. George, Utah (Figure 1-3). The High Point Alignment Alternative would convey the Lake Powell water from High Point Regulating Tank-2 (Alt.) at the high point at ground level elevation 5,630 feet MSL for about 87.5 miles through a buried 69-inch diameter penstock in Kane and Washington counties, Utah and Coconino and Mohave counties, Arizona to Sand Hollow Reservoir near St. George, Utah (Figure 1-3). Four in-line hydro generating stations (HS-1, HS-2 HS-3 and HS-4) with substations located along the penstock would generate electricity and help control water pressure in the penstock. HS-1 would be sited on the south side of U.S. 89 within the Congressionally-designated utility corridor through the GSENM. The High Point Alignment Alternative would include HS-1 (Alt.) along the K4020 road within the GSENM and continue along a portion of the K3290 road.

The proposed penstock alignment and two penstock alignment options are being considered to convey the water from the west GSENM boundary south through White Sage Wash. The proposed penstock



Water Treatment Facility	Hydro System - South Alignment Alternative	Interstate	National Park/Monument
Project Regulating Tank	Water Conveyance System	US Highway	GSENM Boundary
Project Hydro Station	Cedar Valley Pipeline	ST Highway	Tribal Lands
Hurricane Cliffs Forebay/Afterbay	KCWCD Pipeline System	Hwy	State Boundaries
Lakes & Reservoirs		Major Road	County Boundaries
Major Rivers & Streams			

FERC Project Number:
12966-001
BLM Serial Numbers:
AZA-34941
UTU-85472

N

0 1.25 2.5 5 7.5 10 Miles

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR **Figure 1-3** MWH

Lake Powell Pipeline Hydro System South Alternative

alignment would parallel the K3250 road south from U.S. 89 and follow the Pioneer Gap Road alignment around the Shinarump Cliffs. One penstock alignment option would parallel the K3285 road southwest from U.S. 89 and continue to join the Pioneer Gap Road around the Shinarump Cliffs. The other penstock alignment option would extend southwest through currently undeveloped BLM land from the K3290 road into White Sage Wash.

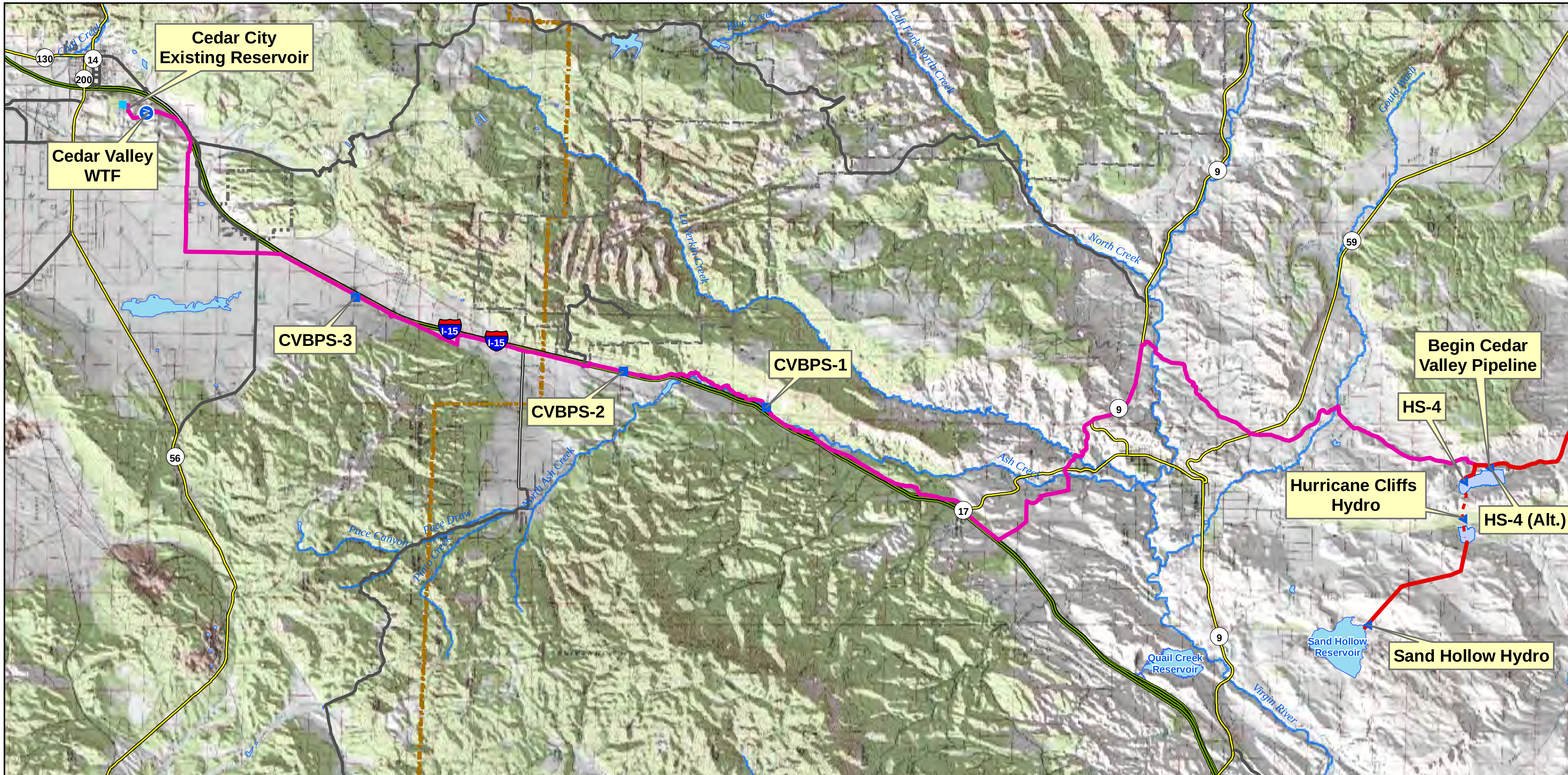
The penstock alignment would continue through White Sage Wash and then parallel to the Navajo-McCullough Transmission Line, crossing U.S. 89 Alt. and Forest Highway 22 toward the southeast corner of the Kaibab Indian Reservation. The penstock alignment would run parallel to and south of the south boundary of the Kaibab Indian Reservation, crossing Kanab Creek and Bitter Seeps Wash, across Moonshine Ridge and Cedar Ridge, and north along Yellowstone Road to Arizona State Route 389 west of the Kaibab Indian Reservation. HS-2 would be sited west of the Kaibab Indian Reservation. The penstock alignment would continue northwest along the south side of Arizona State Route 389 past Colorado City to Hildale City, Utah and HS-3.

The penstock alignment would follow Uzona Road west through Canaan Gap and south of Little Creek Mountain and turn north to HS-4 (Alt.) above the proposed Hurricane Cliffs forebay reservoir. The forebay reservoir would be contained in a valley between a south dam and a north dam and maintain active storage of 11,255 acre-feet of water. A low pressure tunnel would convey the water to a high pressure vertical shaft in the bedrock forming the Hurricane Cliffs, connected to a high pressure tunnel near the bottom of the Hurricane Cliffs. The high pressure tunnel would connect to a penstock conveying the water to a pumped storage hydro generating station. The pumped storage hydro generating station would connect to an afterbay reservoir contained by a single dam in the valley below the Hurricane Cliffs. A low pressure tunnel would convey the water northwest to a penstock continuing on to the Sand Hollow Hydro Station. The water would discharge into the existing Sand Hollow Reservoir.

The peaking hydro generating station option would involve a smaller, 200 acre-foot forebay reservoir with HS-4 discharging into the forebay reservoir, with the peaking hydro generating station discharging to a small afterbay connected to a penstock running north along the existing BLM road and west to the Sand Hollow Hydro Station. A low pressure tunnel would convey the water to a high pressure vertical shaft in the bedrock forming the Hurricane Cliffs, connected to a high pressure tunnel near the bottom of the Hurricane Cliffs. The high pressure tunnel would connect to a penstock conveying the water to a peaking hydro generating station, which would discharge into a 200 acre-foot afterbay reservoir. A penstock would extend north from the afterbay reservoir along the existing BLM road and then west to the Sand Hollow Hydro Station. The water would discharge into the existing Sand Hollow Reservoir.

The **Kane County Pipeline System** would convey the Lake Powell water from the Lake Powell Pipeline at the west GSENM boundary for about 8 miles through a buried 24-inch diameter pipe in Kane County, Utah to a conventional water treatment facility located near the mouth of Johnson Canyon. The pipeline would parallel the south side of U.S. 89 across Johnson Wash and then run north to the new water treatment facility site (Figure 1-3).

The **Cedar Valley Pipeline System** would convey the Lake Powell water from the Lake Powell Pipeline just upstream of HS-4 or HS-4 (Alt.) for about 58 miles through a buried 36-inch diameter pipeline in Washington and Iron counties, Utah to a conventional water treatment facility in Cedar City, Utah (Figure 1-4). Three booster pump stations (CVBPS) located along the pipeline would pump the water under pressure to the new water treatment facility. The pipeline would follow an existing BLM road north from HS-4, cross Utah State Route 59 and continue north to Utah State Route 9, with an aerial crossing of the Virgin River at the Sheep Bridge. The pipeline would run west along the north side of Utah State Route 9 and parallel an existing pipeline through the Hurricane Cliffs at Nephi’s Twist. The pipeline



Water Treatment Facility
Project Pump Station
Project Hydro Station
Hydro System - South Alignment Alternative
Water Conveyance System
Hurricane Cliffs Pressure Tunnel
Cedar Valley Pipeline
Interstate
US Highway
ST Highway
Hwy
Major Road
Hurricane Cliffs Forebay/Afterbay
Lakes & Reservoirs
Major Rivers & Streams
National Park/Monument
County Boundaries
Tribal Lands

FERC Project Number:
12966-001
BLM Serial Numbers:
AZA-34941
UTU-85472

0 1 2 4 6 8 Miles

N

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR **Figure 1-4** MWH

Cedar Valley
Pipeline System

would continue across LaVerkin Creek, cross Utah State Route 17, and make an aerial crossing of Ash Creek. The pipeline would continue northwest to the Interstate 15 corridor and then northeast parallel to the east side of Interstate 15 highway right-of-way. CVBPS-1 would be sited adjacent to an existing gravel pit east of Interstate 15. CVBPS-2 would be sited on private property on the east side of Interstate 15 and south of the Kolob entrance to Zion National Park. CVBPS-3 would be sited on the west side of Interstate 15 in Iron County. The new water treatment facility would be sited near existing water reservoirs on a hill above Cedar City west of Interstate 15.

1.2.2 Existing Highway Alternative

The Existing Highway Alternative consists of five systems: Intake, Water Conveyance, Hydro, Kane County Pipeline, and Cedar Valley Pipeline. The Intake, Water Conveyance and Cedar Valley Pipeline systems would be the same as described for the South Alternative.

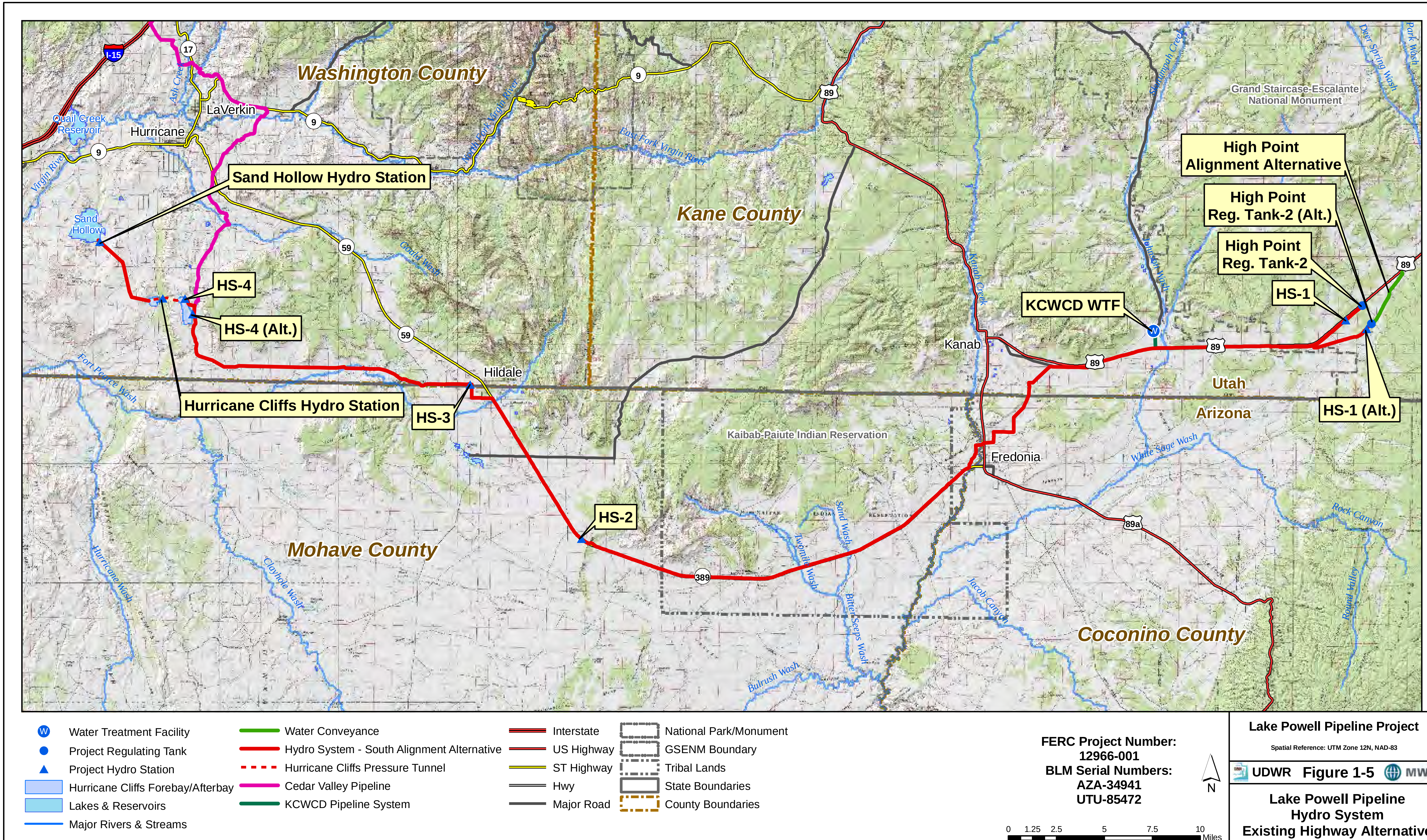
The **Hydro System** would convey the Lake Powell water from the regulating tank at the high point at ground elevation 5,695 feet MSL for about 80 miles through a buried 69-inch diameter penstock in Kane and Washington counties, Utah and Coconino and Mohave counties, Arizona to Sand Hollow Reservoir near St. George, Utah (Figure 1-5). The High Point Alignment Alternative would convey the Lake Powell water from High Point Regulating Tank-2 (Alt.) at the high point at ground level elevation 5,630 feet MSL for about 80.5 miles through a buried 69-inch diameter penstock in Kane and Washington counties, Utah and Coconino and Mohave counties, Arizona to Sand Hollow Reservoir near St. George, Utah (Figure 1-3). The High Point Alignment Alternative would rejoin U.S. 89 about 2.5 miles east of the west boundary of the GSENM. Four in-line hydro generating stations (HS-1, HS-2 HS-3 and HS-4) located along the penstock would generate electricity and help control water pressure in the penstock. HS-1 would be sited on the south side of U.S. 89 within the Congressionally-designated utility corridor through the GSENM. The High Point Alignment Alternative would include HS-1 (Alt.) along the K4020 road within the GSENM and continue along a portion of the K3290 road to its junction with the pipeline alignment along U.S. 89.

The penstock would parallel the south side of U.S. 89 west of the GSENM past Johnson Wash and follow Lost Spring Gap southwest, crossing U.S. 89 Alt. and Kanab Creek in the north end of Fredonia, Arizona. The penstock would run south paralleling Kanab Creek to Arizona State Route 389 and run west adjacent to the north side of this state highway through the Kaibab-Paiute Indian Reservation past Pipe Spring National Monument. The penstock would continue along the north side of Arizona State Route 389 through the west half of the Kaibab-Paiute Indian Reservation to 1.8 miles west of Cedar Ridge (intersection of Yellowstone Road with U.S. 89), from where it would follow the same alignment as the South Alternative to Sand Hollow Reservoir. HS-2 would be sited 0.5 mile west of Cedar Ridge along the north side of Arizona State Route 389.

The **Kane County Pipeline System** would convey the Lake Powell water from the Lake Powell Pipeline crossing Johnson Wash along U.S. 89 for about 1 mile north through a buried 24-inch diameter pipe in Kane County, Utah to a conventional water treatment facility located near the mouth of Johnson Canyon (Figure 1-5).

1.2.3 Southeast Corner Alternative

The Southeast Corner Alternative consists of five systems: Intake, Water Conveyance, Hydro, Kane County Pipeline, and Cedar Valley Pipeline. The Intake, Water Conveyance, Kane County Pipeline and Cedar Valley Pipeline systems would be the same as described for the South Alternative.


Washington County
Kane County
Mohave County
Coconino County
LaVerkin
Hurricane
Quail Creek Reservoir
Sand Hollow
Sand Hollow Hydro Station
HS-4
HS-4 (Alt.)
Hurricane Cliffs Hydro Station
HS-3
HS-2
Hildale
Kanab
Fredonia
KCWCD WTF
High Point Alignment Alternative
High Point Reg. Tank-2 (Alt.)
High Point Reg. Tank-2
HS-1
HS-1 (Alt.)
Grand Staircase-Escalante National Monument
Kaibab-Paiute Indian Reservation
Utah
Arizona
Virgin River
East Fork Virgin River
Kanab Creek
Fort Pearce Wash
Hurricane Wash
Clayhole Wash
Bitter Seeps Wash
Sand Wash
Bulrush Wash
Jacob Canyon
White Sage Wash
Rock Canyon
Deer Spring Wash
Park Wash
Water Treatment Facility
Project Regulating Tank
Project Hydro Station
Hurricane Cliffs Forebay/Afterbay
Lakes & Reservoirs
Major Rivers & Streams
Water Conveyance
Hydro System - South Alignment Alternative
Hurricane Cliffs Pressure Tunnel
Cedar Valley Pipeline
KCWCD Pipeline System
Interstate
US Highway
ST Highway
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Major Road
National Park/Monument
GSENM Boundary
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FERC Project Number:
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AZA-34941
UTU-85472
N
0 1.25 2.5 5 7.5 10 Miles
Lake Powell Pipeline Project
Spatial Reference: UTM Zone 12N, NAD-83
UDWR
Figure 1-5
MWH
Lake Powell Pipeline
Hydro System
Existing Highway Alternative

The **Hydro System** would be the same as described for the South Alternative between High Point Regulating Tank-2 and the east boundary of the Kaibab-Paiute Indian Reservation. The penstock alignment would parallel the north side of the Navajo-McCullough Transmission Line corridor in Coconino County, Arizona through the southeast corner of the Kaibab Indian Reservation for about 3.8 miles and then follow the South Alternative alignment south of the south boundary of the Kaibab-Paiute Indian Reservation, continuing to Sand Hollow Reservoir (Figure 1-6).

1.2.4 Transmission Line Alternatives

Transmission line alternatives include the Intake (3 alignments), BPS-1, Glen Canyon to Buckskin, Buckskin Substation upgrade, Paria Substation upgrade, BPS-2, BPS-2 Alternative, BPS-3 North, BPS-3 South, BPS-3 Underground, BPS-3 Alternative North, BPS-3 Alternative South, BPS-4, BPS-4 Alternative, HS-1 Alternative, HS-2 South, HS-3 Underground, HS-4, HS-4 Alternative, Hurricane Cliffs Afterbay to Sand Hollow, Hurricane Cliffs Afterbay to Hurricane West, Sand Hollow to Dixie Springs, Cedar Valley Pipeline booster pump stations, and Cedar Valley Water Treatment Facility.

The proposed new **Intake Transmission Line** would begin at Glen Canyon Substation and run parallel to U.S. 89 for about 2,500 feet to a new switch station, cross U.S. 89 at the Intake access road intersection and continue northeast to the Intake substation. This 69 kV transmission line would be about 0.9 mile long in Coconino County, Arizona (Figure 1-7). One alternative alignment would run parallel to an existing 138 kV transmission line to the west, turn north to the new switch station, cross U.S. 89 at the Intake access road intersection and continue northeast to the Intake substation. This 69 kV transmission line alternative would be about 1.2 miles long in Coconino County, Arizona (Figure 1-7). Another alternative alignment would bifurcate from an existing transmission line and run west, then northeast to the new switch station, cross U.S. 89 at the Intake access road intersection and continue northeast to the Intake substation. This 69 kV transmission line alternative would be about 1.3 miles long in Coconino County, Arizona (Figure 1-7).

The proposed new **BPS-1 Transmission Line** would begin at the new switch station located on the south side of U.S. 89 and parallel the LPP Water Conveyance System alignment to the BPS-1 substation west of U.S. 89. This 69 kV transmission line would be about 1 mile long in Coconino County, Arizona (Figure 1-7).

The proposed new **Glen Canyon to Buckskin Transmission Line** would consist of a 230 kV transmission line from the Glen Canyon Substation to the Buckskin Substation, running parallel to the existing 138 kV transmission line. This transmission line upgrade would be about 36 miles long through Coconino County, Arizona and Kane County, Utah (Figure 1-7).

The existing **Buckskin Substation** would be upgraded as part of the proposed project to accommodate the additional power loads from the new 230 kV Glen Canyon to Buckskin transmission line. The substation upgrade would require an additional 5 acres of land within the GSENM adjacent to the existing substation in Kane County, Utah (Figure 1-7).

The existing **Paria Substation** would be upgraded as part of the proposed project to accommodate the additional power loads to BPS-4 Alternative. The substation upgrade would require an additional 2 acres of privately-owned land adjacent to the existing substation in Kane County, Utah (Figure 1-7).

The proposed new **BPS-2 Transmission Line** alternative would consist of a new 3-ring switch station along the existing 138 kV Glen Canyon to Buckskin Transmission Line and a new transmission line from the switch station to a new substation west of Big Water and a connection to BPS-2 substation in Kane

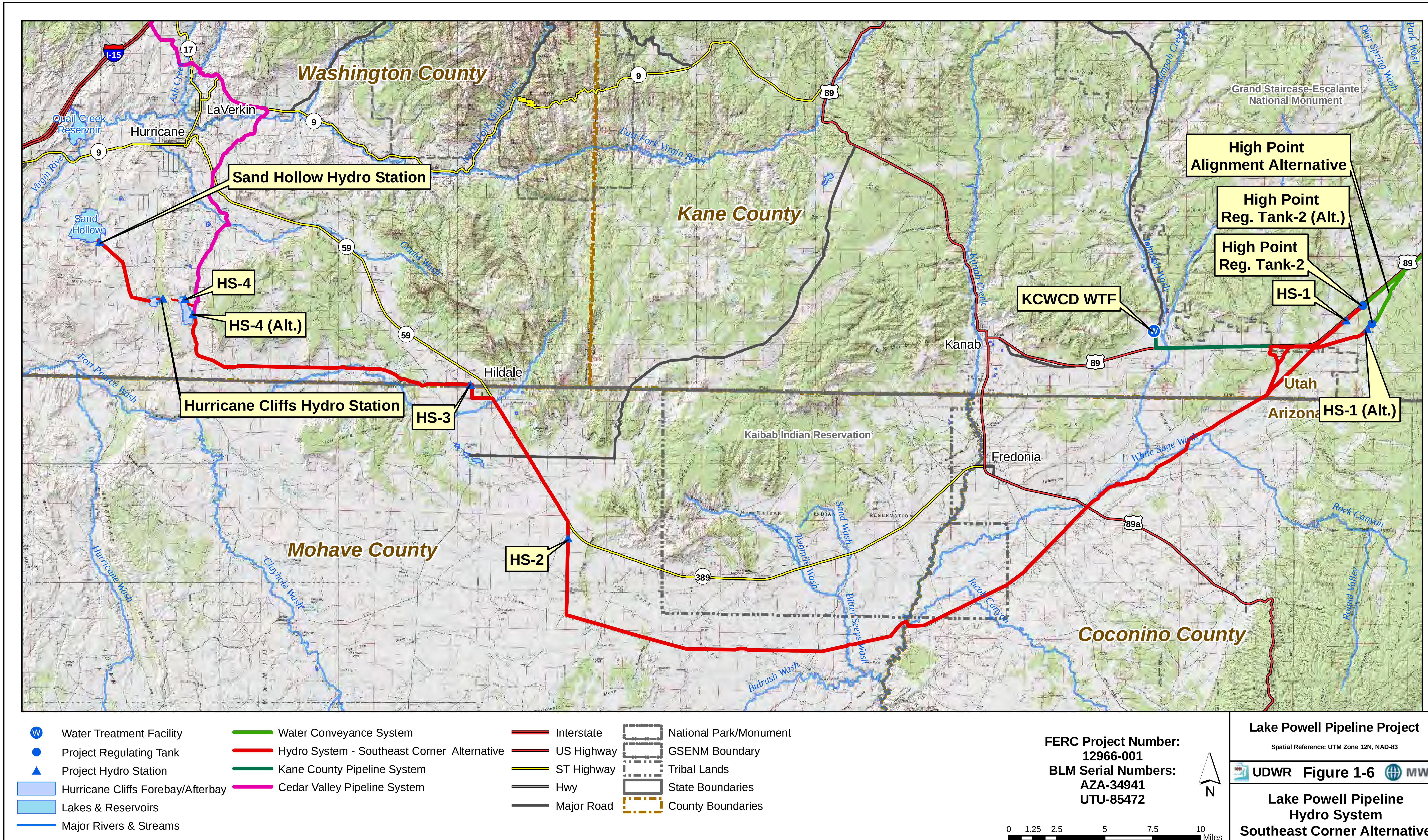
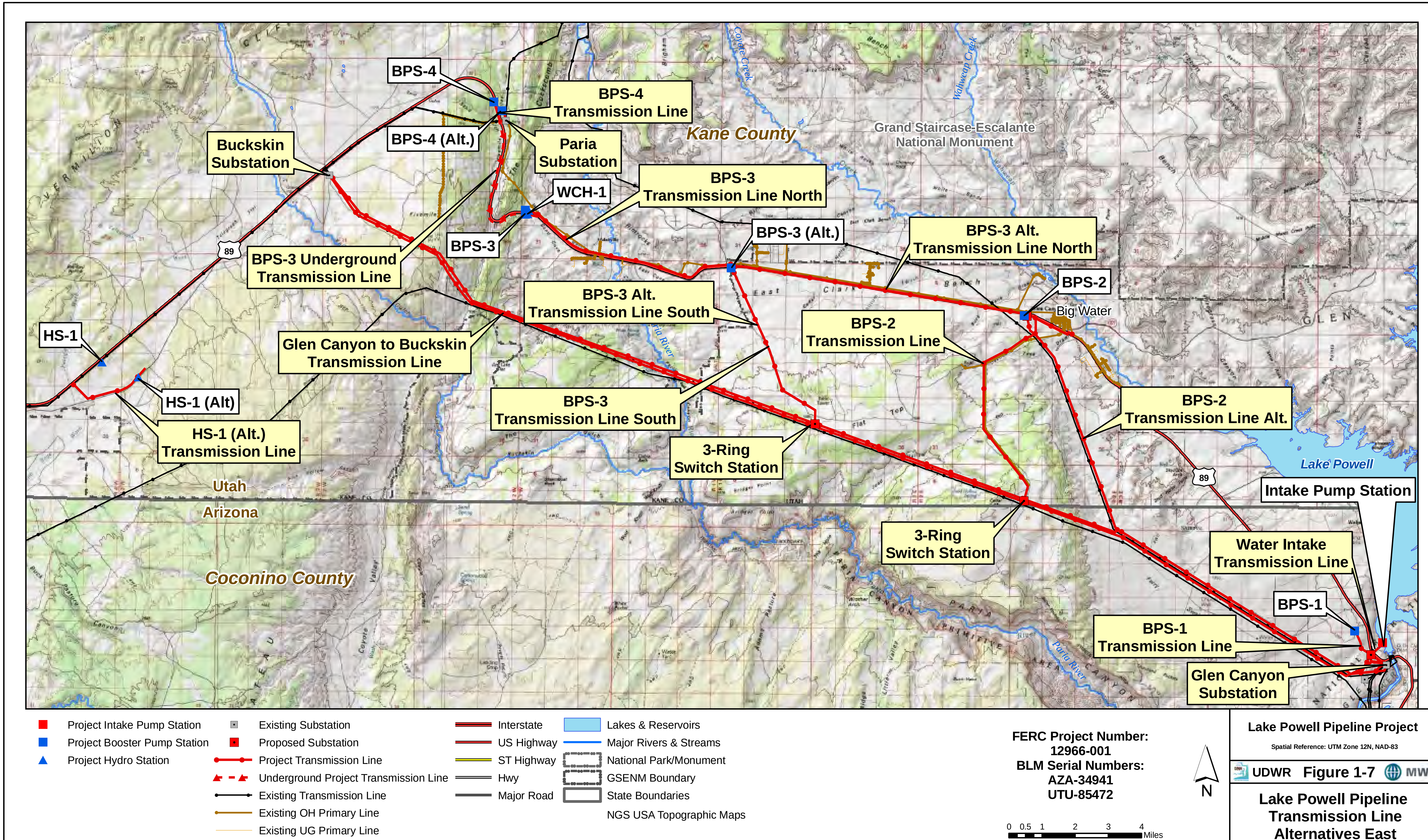


Figure 1-6
Lake Powell Pipeline Hydro System Southeast Corner Alternative


BPS-4
BPS-4 Transmission Line
BPS-4 (Alt.)
Paria Substation
Buckskin Substation
Kane County
Grand Staircase-Escalante National Monument
BPS-3 Transmission Line North
WCH-1
BPS-3
BPS-3 (Alt.)
BPS-3 Alt. Transmission Line North
BPS-3 Underground Transmission Line
BPS-2
Big Water
BPS-3 Alt. Transmission Line South
BPS-2 Transmission Line
Glen Canyon to Buckskin Transmission Line
HS-1
HS-1 (Alt)
HS-1 (Alt.) Transmission Line
BPS-3 Transmission Line South
BPS-2 Transmission Line Alt.
3-Ring Switch Station
Lake Powell
Intake Pump Station
Utah
Arizona
Water Intake Transmission Line
Coconino County
BPS-1
BPS-1 Transmission Line
Glen Canyon Substation
89
Paria River
Project Intake Pump Station
Project Booster Pump Station
Project Hydro Station
Existing Substation
Proposed Substation
Project Transmission Line
Underground Project Transmission Line
Existing Transmission Line
Existing OH Primary Line
Existing UG Primary Line
Interstate
US Highway
ST Highway
Hwy
Major Road
Lakes & Reservoirs
Major Rivers & Streams
National Park/Monument
GSENM Boundary
State Boundaries
NGS USA Topographic Maps
FERC Project Number:
12966-001
BLM Serial Numbers:
AZA-34941
UTU-85472
N
0 0.5 1 2 3 4 Miles
Lake Powell Pipeline Project
Spatial Reference: UTM Zone 12N, NAD-83
UDWR
Figure 1-7
MWH
Lake Powell Pipeline Transmission Line Alternatives East

County, Utah. The new transmission line would parallel an existing distribution line that runs northwest, north and then northeast to Big Water. This new 138 kV transmission line alternative would be about 7 miles long across Utah SITLA-administered land, with a 138 kV connection to the BPS-2 substation (Figure 1-7).

The new **BPS-2 Alternative Transmission Line** would consist of a new 138 kV transmission line from Glen Canyon Substation parallel to the existing Rocky Mountain Power 230 kV transmission line, connecting to the BPS-2 substation west of Big Water. This new 138 kV transmission line alternative would be about 16.5 miles long in Coconino County, Arizona and Kane County, Utah crossing National Park Service-administered land, BLM-administered land and Utah SITLA-administered land (Figure 1-7).

The new **BPS-3 Transmission Line North** alternative would consist of a new 138 kV transmission line from BPS-2 paralleling the south side of U.S. 89 within the Congressionally designated utility corridor west to BPS-3 at the east side of the Cockscomb geological feature. This new 138 kV transmission line alternative would be about 15.7 miles long in Kane County, Utah (Figure 1-7).

The new **BPS-3 Transmission Line South** alternative would consist of a new 3-ring switch station along the existing 138 kV Glen Canyon to Buckskin Transmission Line and a new transmission line from the switch station north along an existing BLM road to U.S. 89 and then west along the south side of U.S. 89 within the Congressionally designated utility corridor to BPS-3 at the east side of the Cockscomb. This new 138 kV transmission line alternative would be about 12.3 miles long in Kane County, Utah (Figure 1-7).

The new **BPS-3 Underground Transmission Line** alternative would consist of a new buried 24.9 kV transmission line (2 circuits) from the upgraded Paria Substation to BPS-3 on the east side of the Cockscomb geological feature. This new underground transmission line would be parallel to the east and south side of U.S. 89 and would be about 4.1 miles long in Kane County, Utah (Figure 1-7).

The new **BPS-3 Alternative Transmission Line North** alternative would consist of a new 138 kV transmission line from BPS-2 paralleling the south side of U.S. 89 west to BPS-3 Alternative near the GSENM east boundary within the Congressionally-designated utility corridor. This new 138 kV transmission line alternative would be about 9.3 miles long in Kane County, Utah (Figure 1-7).

The proposed new **BPS-3 Alternative Transmission Line South** alternative would consist of a new 3-ring switch station along the existing 138 kV Glen Canyon to Buckskin Transmission Line and a new transmission line from the switch station north along an existing BLM road to BPS-3 Alternative near the GSENM east boundary and within the Congressionally-designated utility corridor. This new 138 kV transmission line alternative would be about 5.9 miles long in Kane County, Utah (Figure 1-7).

The new **BPS-4 Transmission Line** alternative would begin at the upgraded Paria Substation and run parallel to the west side of U.S. 89 north to BPS-4 within the Congressionally designated utility corridor. This new 138 kV transmission line would be about 0.8 mile long in Kane County, Utah (Figure 1-7).

The proposed new **BPS-4 Alternative Transmission Line** would begin at the upgraded Paria Substation and run north to the BPS-4 Alternative. This 69 kV transmission line would be about 0.4 mile long in Kane County, Utah (Figure 1-7).

The proposed new **HS-1 Alternative Transmission Line** would begin at the new HS-1 Alternative and run southwest parallel to the K4020 road and then northwest parallel to the K4000 road to the U.S. 89 corridor where it would tie into the existing 69 kV transmission line from the Buckskin Substation to the

Johnson Substation. This 69 kV transmission line would be about 3 miles long in Kane County, Utah (Figure 1-7).

The proposed new **HS-2 South Transmission Line** alternative would connect the HS-2 hydroelectric station and substation along the South Alternative to an existing 138 kV transmission line paralleling Arizona State Route 389. This new 34.5 kV transmission line would be about 0.9 mile long in Mohave County, Arizona (Figure 1-8).

The proposed new **HS-3 Underground Transmission Line** would connect the HS-3 hydroelectric station and substation to the existing Twin Cities Substation in Hildale City, Utah. The new 12.47 kV underground circuit would be about 0.6 mile long in Washington County, Utah (Figure 1-8).

The proposed new **HS-4 Transmission Line** would consist of a new transmission line from the HS-4 hydroelectric station and substation north along an existing BLM road to an existing transmission line parallel to Utah State Route 59. The new 69 kV transmission line would be about 8.2 miles long in Washington County, Utah (Figure 1-8).

The new **HS-4 Alternative Transmission Line** alternative would connect the HS-4 Alternative hydroelectric station and substation to an existing transmission line parallel to Utah State Route 59. The new 69 kV transmission line would be about 7.5 miles long in Washington County, Utah (Figure 1-8).

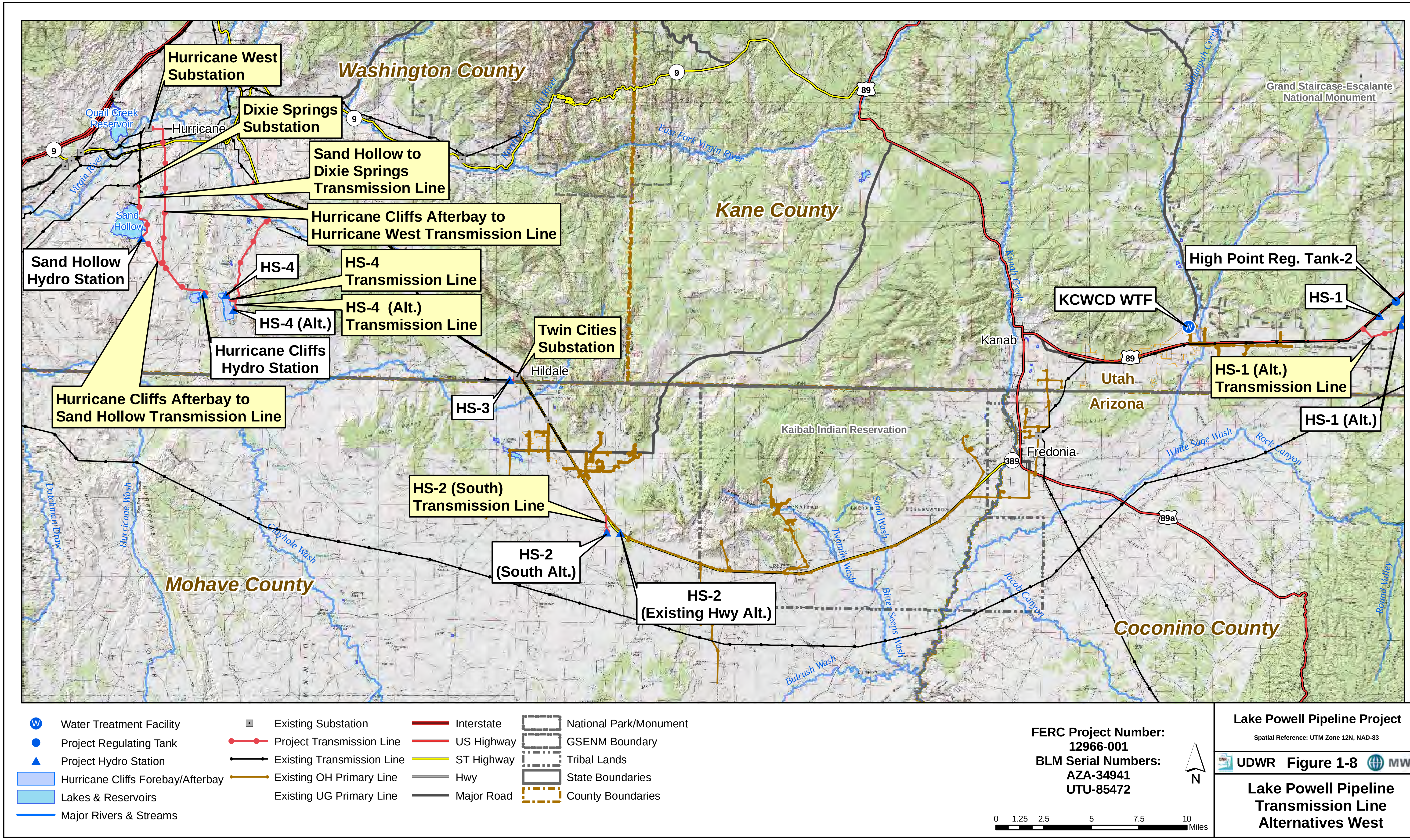
The proposed new **Hurricane Cliffs Afterbay to Sand Hollow Transmission Line** would consist of a new 69 kV transmission line from the Hurricane Cliffs peaking power plant and substation, and run northwest to the Sand Hollow Hydro Station substation. This new 69 kV transmission line would be about 4.9 miles long in Washington County, Utah (Figure 1-8).

The proposed new **Hurricane Cliffs Afterbay to Hurricane West Transmission Line** would consist of a new 345 kV transmission line from the Hurricane Cliffs pumped storage power plant and run northwest and then north to the planned Hurricane West 345 kV substation. This new 345 kV transmission line would be about 10.9 miles long in Washington County, Utah (Figure 1-8).

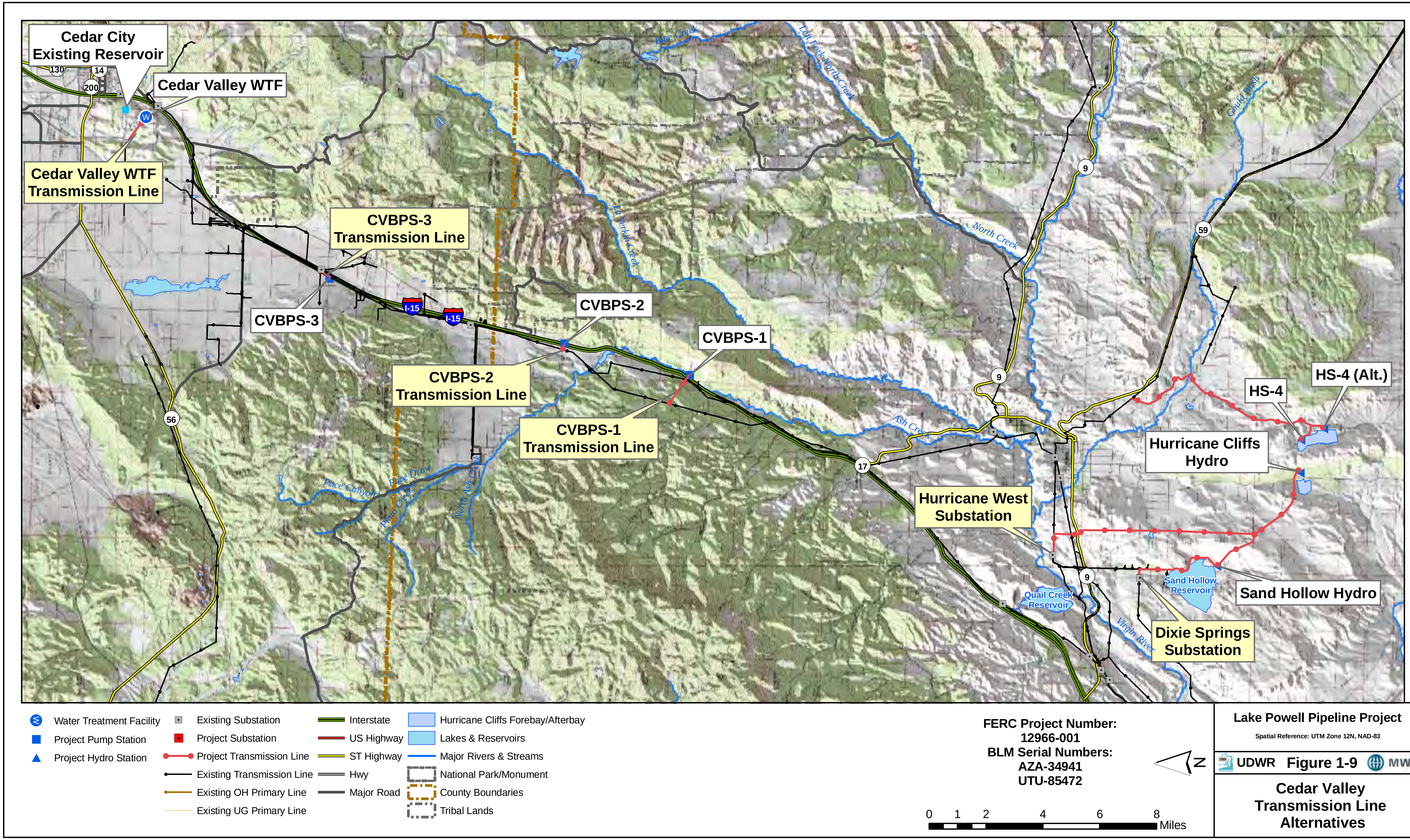
The proposed new **Sand Hollow to Dixie Springs Transmission Line** would consist of a new 69 kV transmission line from the Sand Hollow Hydro Station substation around the east side of Sand Hollow Reservoir and north to the existing Dixie Springs Substation. This new 69 kV transmission line would be about 3.4 miles long in Washington County, Utah (Figure 1-8).

The three **Cedar Valley Pipeline** booster pump stations would require new transmission lines from existing transmission lines paralleling the Interstate 15 corridor. The new CVBPS-1 transmission line would extend southeast over I-15 from the existing transmission line to the booster pump station substation for about 1.3 miles in Washington County, Utah (Figure 1-9). The new CVBPS-2 transmission line would extend east over I-15 from the existing transmission line to the booster pump station substation for about 0.2 mile in Washington County, Utah (Figure 1-9). The new CVBPS-3 transmission line would extend west over I-15 from the existing transmission line and southwest along the west side of Interstate 15 to the booster pump station substation for about 0.6 mile in Iron County, Utah (Figure 1-9).

The **Cedar Valley Water Treatment Facility Transmission Line** would begin at an existing substation in Cedar City and run about 1 mile to the water treatment facility site in Iron County, Utah (Figure 1-9).



Hurricane West Substation
Dixie Springs Substation
Sand Hollow to Dixie Springs Transmission Line
Hurricane Cliffs Afterbay to Hurricane West Transmission Line
Sand Hollow Hydro Station
HS-4
HS-4 Transmission Line
HS-4 (Alt.)
HS-4 (Alt.) Transmission Line
Hurricane Cliffs Hydro Station
Hurricane Cliffs Afterbay to Sand Hollow Transmission Line
Twin Cities Substation
HS-3
HS-2 (South) Transmission Line
HS-2 (South Alt.)
HS-2 (Existing Hwy Alt.)
KCWCD WTF
High Point Reg. Tank-2
HS-1
HS-1 (Alt.) Transmission Line
HS-1 (Alt.)
Washington County
Kane County
Mohave County
Coconino County
Grand Staircase-Escalante National Monument
Kaibab Indian Reservation
Quail Creek Reservoir
Hurricane
Sand Hollow
Hildale
Kanab
Fredonia
Utah
Arizona
Virgin River
East Fork Virgin River
North Fork Virgin River
Kanab Creek
Johnson Creek
White Sage Wash
Rock Canyon
Cottonwood Canyon
Clayhole Wash
Hurricane Wash
Dutchman Draw
Sand Wash
Twomile Wash
Bitter Seeps Wash
Jacob Canyon
Bulrush Wash
Round Valley
9
89
89a
389
Water Treatment Facility
Project Regulating Tank
Project Hydro Station
Hurricane Cliffs Forebay/Afterbay
Lakes & Reservoirs
Major Rivers & Streams
Existing Substation
Project Transmission Line
Existing Transmission Line
Existing OH Primary Line
Existing UG Primary Line
Interstate
US Highway
ST Highway
Hwy
Major Road
National Park/Monument
GSENM Boundary
Tribal Lands
State Boundaries
County Boundaries
FERC Project Number: 12966-001
BLM Serial Numbers: AZA-34941 UTU-85472
N
0 1.25 2.5 5 7.5 10 Miles
Lake Powell Pipeline Project
Spatial Reference: UTM Zone 12N, NAD-83
UDWR
Figure 1-8
MWH
Lake Powell Pipeline Transmission Line Alternatives West



Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR Figure 1-9 MWH

Cedar Valley Transmission Line Alternatives

1.3 Summary Description of No Lake Powell Water Alternative

The No Lake Powell Water Alternative would involve a combination of developing remaining available surface water and groundwater supplies, developing reverse osmosis treatment of existing low quality water supplies, and reducing residential outdoor water use in the WCWCD and CICWCD service areas. This alternative could provide a total of 86,249 acre-feet of water annually to WCWCD, CICWCD and KCWCD for M&I use without diverting Utah's water from Lake Powell.

1.3.1 WCWCD No Lake Powell Water Alternative

The WCWCD would implement other future water development projects currently planned by the District, develop additional water reuse/reclamation, and convert additional agricultural water use to M&I use as a result of urban development in agricultural areas through 2020. Remaining planned and future water supply projects through 2020 include the Ash Creek Pipeline (5,000 acre-feet per year), Crystal Creek Pipeline (2,000 acre-feet per year), and Quail Creek Reservoir Agricultural Transfer (4,000 acre-feet per year). Beginning in 2020, WCWCD would convert agricultural water to secondary use and work with St. George City to maximize existing wastewater reuse, bringing the total to 96,258 acre-feet of water supply per year versus demand of 98,427 acre-feet per year, incorporating currently mandated conservation goals. The WCWCD water supply shortage in 2037 would be 70,000 acre-feet per year, 1,000 acre-feet more than the WCWCD maximum share of the LPP water. Therefore, the WCWCD No Lake Powell Water Alternative needs to develop 69,000 acre-feet of water per year to meet comparable supply and demand requirements as the other action alternatives.

The WCWCD would develop a reverse osmosis (RO) advanced water treatment facility near the Washington Fields Diversion in Washington County, Utah to treat up to 40,000 acre-feet per year of Virgin River water with high total dissolved solids (TDS) concentration and other contaminants. The RO advanced water treatment facility would produce up to 36,279 acre-feet per year of water suitable for M&I use. The WCWCD would develop the planned Warner Valley Reservoir to store the diverted Virgin River water, which would be delivered to the RO advanced water treatment facility. The remaining 3,721 acre-feet per year of brine by-product from the RO treatment process would require evaporation and disposal meeting State of Utah water quality regulations.

The remaining needed water supply of 32,721 acre-feet per year to meet WCWCD 2037 demands would be obtained by reducing and restricting outdoor residential water use in the WCWCD service area. The Utah Division of Water Resources (UDWR) estimated 2005 culinary water use for residential outdoor watering in the communities served by WCWCD was 97.4 gallons per capita per day (gpcd) (UDWR 2009). This culinary water use rate is reduced by 30.5 gpcd to account for water conservation attained from 2005 through 2020, yielding 66.9 gpcd residential outdoor water use available for conversion to other M&I uses. The equivalent water use rate reduction to generate 32,721 acre-feet per year of conservation is 56.6 gpcd for the 2037 population within the WCWCD service area. Therefore, beginning in 2020, the existing rate of residential outdoor water use would be gradually reduced and restricted to 10.3 gpcd, or an 89.4 percent reduction in residential outdoor water use.

The combined 36,279 acre-feet per year of RO product water and 32,721 acre-feet per year of reduced residential outdoor water use would equal 69,000 acre-feet per year of M&I water to help meet WCWCD demands through 2037.

1.3.2 CICWCD No Lake Powell Water Alternative

The CICWCD would implement other future groundwater development projects currently planned by the District, purchase agricultural water from willing sellers for conversion to M&I uses, and convert additional agricultural water use to M&I use as a result of urban development in agricultural areas through 2020. Remaining planned and future water supply projects through 2020 include additional groundwater development projects (3,488 acre-feet per year), agricultural conversion resulting from M&I development (3,834 acre-feet per year), and purchase agricultural water from willing sellers (295 acre-feet per year). Beginning in 2020, CICWCD would have a total 19,772 acre-feet of water supply per year versus demand of 19,477 acre-feet per year, incorporating required progressive conservation goals. The CICWCD water supply shortage in 2060 would be 11,470 acre-feet per year. Therefore, the CICWCD No Lake Powell Water Alternative needs to develop 11,470 acre-feet of water per year to meet comparable supply and demand limits as the other action alternatives.

The remaining needed water supply of 11,470 acre-feet per year to meet CICWCD 2060 demands would be obtained by reducing and restricting outdoor residential water use in the CICWCD service area. The UDWR estimated 2005 culinary water use for residential outdoor watering in the communities served by CICWCD was 84.5 gpcd (UDWR 2007). A portion of this residential outdoor water would be converted to other M&I uses. The equivalent water use rate to obtain 11,470 acre-feet per year is 67.8 gpcd for the 2060 population within the CICWCD service area. Therefore, the existing rate of residential outdoor water use would be gradually reduced and restricted to 16.7 gpcd beginning in 2023, an 80 percent reduction in the residential outdoor water use rate between 2023 and 2060. The 11,470 acre-feet per year of reduced residential outdoor water use would be used to help meet the CICWCD demands through 2060.

1.3.3 KCWCD No Lake Powell Water Alternative

The KCWCD would use existing water supplies and implement future water development projects including new groundwater production, converting agricultural water rights to M&I water rights as a result of urban development in agricultural areas, and developing water reuse/reclamation. Existing water supplies (4,039 acre-feet per year) and 1,994 acre-feet per year of new ground water under the No Lake Powell Water Alternative would meet projected M&I water demand of 6,033 acre-feet per year within the KCWCD service area through 2060. The total potential water supply for KCWCD is about 12,140 acre-feet per year (4,039 acre-feet per year existing culinary plus secondary supply, and 8,101 acre-feet per year potential for additional ground water development up to the assumed sustainable ground water yield) without agricultural conversion to M&I supply. Short-term ground water overdrafts and new storage projects (e.g., Jackson Flat Reservoir) would provide reserve water supply to meet demands during drought periods and other water emergencies.

1.4 Summary Description of the No Action Alternative

No new intake, water conveyance or hydroelectric features would be constructed or operated under the No Action Alternative. The Utah Board of Water Resources' Colorado River water rights consisting of 86,249 acre-feet per year would not be diverted from Lake Powell and would continue to flow into the Lake until the water is used for another State of Utah purpose or released according to the operating guidelines. Future population growth as projected by the Utah Governor's Office of Planning and Budget (GOPB) would continue to occur in southwest Utah until water and other potential limiting resources such as developable land, electric power, and fuel begin to curtail economic activity and population in-migration.

1.4.1 WCWCD No Action Alternative

The WCWCD would implement other future water development projects currently planned by the District, develop additional water reuse/reclamation, convert additional agricultural water use to M&I use as a result of urban development in agricultural areas, and implement advanced treatment of Virgin River water. The WCWCD could also limit water demand by mandating water conservation measures such as outdoor watering restrictions. Existing and future water supplies under the No Action Alternative would meet projected M&I water demand within the WCWCD service area through approximately 2020. The 2020 total water supply of about 96,528 acre-feet per year would include existing supplies, planned WCWCD water supply projects, wastewater reuse, transfer of Quail Creek Reservoir supplies, and future agricultural water conversion resulting from urban development of currently irrigated lands. Each future supply source would be phased in as needed to meet the M&I demand associated with the forecasted population. The No Action Alternative would not provide WCWCD with any reserve water supply (e.g., water to meet annual shortages because of drought, emergencies, and other losses). Maximum reuse of treated wastewater effluent for secondary supplies would be required to meet the projected M&I water demand starting in 2020. The No Action Alternative would not provide adequate water supply to meet projected water demands from 2020 through 2060. There would be a potential water shortage of approximately 139,875 acre-feet per year in 2060 under the No Action Alternative (UDWR 2008b).

1.4.2 CICWCD No Action Alternative

The CICWCD would implement future water development projects including converting agricultural water rights to M&I water rights as a result of urban development in agricultural areas, purchasing "buy and dry" agricultural water rights to meet M&I demands, and developing water reuse/reclamation. The Utah State Engineer would act to limit existing and future ground water pumping from the Cedar Valley aquifer in an amount not exceeding the assumed sustainable yield of 37,600 ac-ft per year. Existing and future water supplies under the No Action Alternative meet projected M&I water demand within the CICWCD service area during the planning period through agricultural conversion of water rights to M&I use, wastewater reuse, and implementing "buy and dry" practices on irrigated agricultural land. Each future water supply source would be phased in as needed to meet the M&I demand associated with the forecasted population. The CICWCD No Action Alternative includes buying and drying of agricultural water rights covering approximately 8,000 acres between 2005 and 2060 and/or potential future development of West Desert water because no other potential water supplies have been identified to meet unmet demand. The No Action Alternative would not provide CICWCD with any reserve water supply (e.g., water to meet annual shortages because of drought, emergencies, and other losses) after 2010 (i.e., after existing supplies would be maximized).

1.4.3 KCWCD No Action Alternative

The KCWCD would use existing water supplies and implement future water development projects including new ground water production, converting agricultural water rights to M&I water rights as a result of urban development in agricultural areas, and developing water reuse/reclamation. Existing water supplies (4,039 acre-feet per year) and 1,994 acre-feet per year of new ground water under the No Action Alternative would meet projected M&I water demand of 6,033 acre-feet per year within the KCWCD service area through 2060. The total potential water supply for KCWCD is about 12,140 acre-feet per year (4,039 acre-feet per year existing culinary plus secondary supply, and 8,101 acre-feet per year potential for additional ground water development up to the assumed sustainable ground water yield) without agricultural conversion to M&I supply. Short-term ground water overdrafts and new storage projects (e.g., Jackson Flat Reservoir) would provide reserve water supply to meet demands during drought periods and other water emergencies.

1.5 Identified Issues

1.5.1 Purposes of Study

This technical report describes the results and findings of a preliminary geologic survey performed to evaluate conditions along the proposed alternative pipeline alignments of the LPP Project (Project). The purpose of the survey, as defined in the 2008 Geology and Soils Study Plan (UBWR 2008) prepared for the Federal Energy Regulatory Commission (FERC), was to identify potential impacts of geologic and soil conditions on the Project during construction and operation, document the potential influence of soil and geologic conditions on Project features, and identify measures to mitigate impacts of the geology and soils conditions.

The primary objectives of the geology and soils survey with regard to geology included elements intended to help provide information for pipeline design, as well as to determine the impacts of construction, operation, and maintenance of the Project on geologic resources and, conversely, the impact of geologic features on the Project. While these two needs included substantial overlap, they have been documented in separate reports. This report documents the components of the geology and soils survey that addressed the impacts of the Project on geologic resources, as well as the impact of geologic resources on the Project.

Additional studies were undertaken to evaluate impacts associated with groundwater resources and to evaluate engineering conditions at tunnels, shafts, and reservoirs. These are documented in separate reports.

1.5.2 Identified Issues

The geologic and soils issued identified in the Geology and Soils Study Plan for analyses include the following:

- Estimating fault locations and determination of fault activity
- Field survey for potential unidentified fault locations (minor faults, fault zone displacements, fault spurs, etc.)
- Determining known seismic activity – magnitude and acceleration
- Determining rates and magnitudes of past and probable future fault displacements at locations where the Project would cross faults where a risk of fault activity has been identified
- Identifying locations and types of soil and rock conditions subject to liquefaction
- Risk of liquefaction occurrence
- Identifying landslides, potentially unstable slopes, and related features
- Identifying locations along the alternative alignments where soil and/or rock conditions have been or may be conducive to subsidence, expansion, or collapse, including soluble rock and soil such as gypsum deposits and limestone with solution cavities, clay deposits, alluvial fans, and loess.
- Characterizing locations at risk of landslides, rock falls, debris flows, and other geologic hazards
- Characterizing the possible risks to Project features and to human safety associated with geologic hazards that could be affected by Project features

- Identifying potential effects of construction blasting on nearby rock and soil stability, buildings and other structures, natural gas or municipal pipelines, water wells, and other features
- Characterizing specific types of soils along alternative alignments
- Estimating engineering characteristics of soils at selected locations along alternative alignments
- Identifying rock engineering characteristics pertaining to excavation, tunneling, removal and disposal along alternative alignments
- Determining the presence of groundwater, at what levels and within what range of fluctuations within the alternative alignments
- Estimating groundwater inflow rates into excavations and tunnels
- Estimating soil and rock strength characteristics at the Lake Powell Intake and Hurricane Cliffs Hydropower Facilities
- Recommending mitigation measures for problems and hazards associated with geologic and soils features
- Identifying best methods and locations for reuse and/or disposal of waste rock and soil resulting from Project construction
- Identifying best methods and locations for obtaining rock and soil for Project construction
- Identifying mineral deposits within the pipeline alignments subject to mineral disposal rules under the requirements of 43 CFR 3600, and identify characteristics of mineral deposits required for permitting (free use or sale)

Issues associated with engineering requirements for construction of the pipeline, intake, shafts, and other features were addressed during the study but are not included in this report unless the results pertain directly to geology and soil resources impacts. A separate engineering report was prepared to facilitate engineering requirements and provide more extensive descriptions of general rock and soil characteristics. Groundwater resource impacts are presented in a separate resource technical report (MWH 2010).

1.6 Impact Topics

The following impact topics are addressed in the Geology and Soil Resources Study Report:

- Would fault movement damage the LPP or CVP pipelines, resulting in releases that would have a significant impact on geology and soils? If so, what impacts would occur?
- Would seismic activity create conditions that would damage the LPP or CVP pipelines, resulting in releases that would have a significant impact on geology and soils? If so, what impacts would occur?
- Are potentially unstable slopes found in the areas of impact of the LPP or CVP pipelines that would be at risk for failure (landslides, rockfalls, debris flows, or other geologic hazards) due to construction or operation of the pipelines? Would the failure cause risk to human life or the environment?
- Do conditions along the LPP or CVP pipelines present a significant risk of subsidence due to collapsible soils, dissolution of gypsum or other soluble rock or soil, or collapse of subsurface

cavities that would damage the pipelines, resulting in releases that would have a significant impact on geology and soils? If so, what impacts would occur?

- Would construction or operation of the LPP or CVP pipelines result in conditions that would present a risk to human health or safety associated with geologic hazards? If so, what impacts would occur?
- Would construction activities, in particular but not limited to blasting, present a significant risk to important human structures, including but not limited to existing pipelines, buildings, wells, and major roads? If so, what impacts would occur?
- Is there a significant risk of pipeline, tunnel, shaft, or appurtenance failure due to rock and/or soil characteristics? If so, why, and what impacts would occur?
- Will excess or unsuitable excavated rock or soil occur during construction of the LPP or CVP pipelines? If so, which materials will be unsuitable, and how and where will the materials be disposed of? Will this have a significant impact on geology and soils?
- Will it be necessary to import rock or soil for pipeline and/or appurtenance construction? If so, from where will this material come, and will this have a significant impact on geology and soils?

Chapter 2
Methodology

2.1 General

Information was obtained and developed for this study by performing a review of relevant available reports and maps and by performing a field survey of geologic conditions along the alternative pipeline alignments. These activities are described hereafter.

2.2 Assumptions

The following assumptions were used in performing this study:

- Stable soil and rock conditions would continue to remain stable
- Dormant or inactive faults and fault zones (no activity in the past 10,000 years) would remain so for the lifetime of the Project
- No significant additional human development would occur in the pipeline right of way before construction of the pipeline and appurtenances
- Future development near the pipeline right of way and appurtenances will be subject to restrictions to prevent construction near blowoff valves and other active features and to allow unobstructed access for operations and maintenance
- Disposal of spoils will be allowed on-site by spreading of excess excavated materials in a thin layer across the pipeline right-of-way on both public and private land, as indicated for lands under its jurisdiction by U.S. Department of Interior, Bureau of Land Management (BLM) personnel during performance of this study
- Stream channels and washes that are dry most of the year flow as a direct result of specific precipitation events and/or snowmelt runoff and do not intercept groundwater
- All construction and operations/maintenance (O&M) activities would be performed using Best Management Practices (BMPs) to minimize or prevent slope instability or erosion caused by construction, operations, or maintenance of the pipeline and appurtenances
- All construction and O&M activities will comply with health and safety requirements of the Occupational Safety and Health Administration (OSHA)
- Project design will be performed using appropriate design parameters to minimize risks associated with fault displacement, seismic activity, expansive and collapsible soils, subsidence, compaction requirements, etc.
- Spoils and areas disturbed during construction will be seeded with appropriate vegetation and stabilized as needed to prevent erosion.

2.3 Data Used

The information that was reviewed for this study included the following maps and documents. The complete references are found in Chapter 8:

- Arizona Bureau of Mines (ABM). 1959. Geologic map of Mohave County, Arizona
- ABM. 1960. Geologic map of Coconino County, Arizona
- Fugro William Lettis and Associates (FWLA). 2009. Geologic Characterization of Multiple Fault Crossings along the Proposed Lake Powell and Cedar Valley Pipelines, Hurricane Cliffs Hydropower Facility, Iron, Washington and Kane Counties, Utah and Mohave and Coconino Counties, Arizona
- MWH Americas (MWH). 2009a. Lake Powell Pipeline Phase I – Preliminary Engineering and Environmental Studies, Task 5 – Develop and Analyze Alternatives, Technical Memorandum 5.11 - Geological, Geotechnical and Foundation Conditions
- MWH. 2009b. Lake Powell Pipeline Phase II – Preliminary Engineering and Environmental Studies, Task 6 – Conceptual Design Report
- MWH. 2009c. Lake Powell Pipeline Phase II – Preliminary Engineering and Environmental Studies, Task 6 – Conceptual Design Report, Appendix B – Special Crossings Details
- MWH. 2010. Groundwater Resources Technical Report.
- Natural Resources Conservation Service (NRCS). 1971. Soil survey of Washington County area, Utah
- NRCS. 1983. Soil survey of Coconino County area, Arizona, North Kaibab Part
- NRCS. 1996. Soil survey of Iron-Washington area, parts of Iron, Kane, and Washington Counties
- NRCS. 2003. Soil survey of Grand Staircase-Escalante National Monument area, parts of Kane and Garfield Counties, Utah
- NRCS. 2007a. Soil survey of Coconino County area, Arizona, north Kaibab part
- NRCS. 2007b. Soil survey of Grand Staircase-Escalante National Monument area, parts of Kane and Garfield Counties, Utah
- NRCS. 2007c. Soil survey of Iron-Washington area, parts of Iron, Kane, and Washington Counties
- NRCS. 2007d. Soil survey of Washington County area, Utah
- U.S. Geological Survey (USGS). 1963. Geology of the Lees Ferry area, Coconino County, Arizona: U.S. Geological Survey Bulletin 1137
- USGS. 2004a. Geologic map of the Kanab 30’ x 60’ quadrangle, Utah and Arizona: U.S. Geological Survey Geologic Investigations Series I-2655
- USGS. 2004b. Geologic map of the Pipe Spring National Monument and the western Kaibab-Paiute Reservation, Mohave County, Arizona: U.S. Geological Survey Scientific Investigations Map 2863
- USGS. 2009. Hazard Mapping Images and Data: USGS National Seismic Hazard Maps, Data, and Documentation.

- Utah Geological and Mineral Survey (UGMS). 1989. Geology of Kane County, Utah – Geologic Hazard Map. Bulletin 124
- Utah Geological Survey (UGS). 1995a. Geologic map of the Hildale quadrangle, Washington and Kane Counties, Utah and Mojave County, Arizona: Utah Geological Survey Map 167
- UGS. 1995b. Geologic map of the New Harmony Quadrangle, Washington County, Utah: Utah Geological Survey Miscellaneous Publications 95-2
- UGS. 1999. Digital geologic map of the Kanab 30' x 60' quadrangle, Kane and Washington Counties, Utah and Coconino County, Arizona: Utah Geological Survey Open-File Report 366
- UGS. 2001. Geologic map of the Smithsonian Butte quadrangle, Washington County, Utah: Utah Geological Survey Miscellaneous Publication 01-1
- UGS. 2003a. Geologic map of the Harrisburg Junction 7.5' quadrangle, Washington County, Utah: Utah Geological Survey Map 191
- UGS. 2003b. Geologic map of the Hurricane 7.5' quadrangle, Washington County, Utah: Utah Geological Survey Map 187
- UGS. 2003c. Geologic map of the Pintura quadrangle, Washington County, Utah: Utah Geological Survey Map 196
- UGS. 2004a. Geologic Map of the Divide quadrangle, Washington County, Utah: Utah Geological Survey Map 197
- UGS. 2004b. Geologic Map of the Little Creek Mountain quadrangle, Washington County, Utah: Utah Geological Survey Map 204
- UGS. 2005. Geologic Map of the Washington Dome Quadrangle, Washington County, Utah: Utah Geological Survey Map 209
- UGS. 2006a. Geologic Map of the Smoky Mountain 30' x 60' quadrangle, Kane and San Juan Counties, Utah, and Coconino County, Arizona: Utah Geological Survey Map 213
- UGS. 2006b. Interim geologic map of the Cedar City 30' x 60' quadrangle, Iron and Washington Counties, Utah: Utah Geological Survey Open-File Report 476DM
- UGS. 2007. Interim Geologic Map of the St. George 30' x 60' Quadrangle and the east part of the Clover Mountain 30' x 60' Quadrangle, Washington and Iron Counties, Utah: Utah Geological Survey Open-File Report 478
- UGS. 2008a. Collapsible-Soil-Susceptibility Map for the St. George-Hurricane Metropolitan Area. Special Study 127, Plate 7
- UGS. 2008b. Expansive-Soil-and Rock-Susceptibility Map for the St. George-Hurricane Metropolitan Area. Special Study 127, Plate 6
- UGS. 2008c. Gypsiferous-Soil-and Rock-Susceptibility Map for the St. George-Hurricane Metropolitan Area. Special Study 127, Plate 8
- UGS. 2008d. Landslide-Hazard Map for the St. George-Hurricane Metropolitan Area. Special Study 127, Plate 4
- UGS. 2008e. Shallow-Bedrock-Susceptibility Map for the St. George-Hurricane Metropolitan Area. Special Study 127, Plate 10
- UGS. 2008f. Surface-Fault-Rupture-Hazard Map for the St. George-Hurricane Metropolitan Area. Special Study 127, Plate 1

- UGS. 2009. Presentation regarding the Enoch earth fissure. Presented to the Central Iron County Water Conservancy District, June 11, 2009.
- Washington County Water Conservancy District (WCWCD). 2005. Geology along the route of the Lake Powell water pipeline, Utah and Arizona: Washington County Water Conservancy District Report WCWCD-02.

2.4 Impact Analysis Methodology

2.4.1 Fault Movement Impacts

Faults were identified as part of the field survey. Major faults were evaluated for hazard potential by Fugro William Lettis and Associates (FWLA). Their findings are incorporated into this report. A report of FWLA's findings is included as Attachment A.

2.4.2 Seismic Activity Impacts

The hazards associated with seismic activity were evaluated by identifying locations where the potential for a large-magnitude earthquake could occur in vicinity of the pipeline alignments using seismic hazard maps prepared by the U.S. Geological Survey (USGS). Specifically, locations where the pipeline alignments were within zones of high probability of Peak Ground Acceleration (PGA) were identified with a two-percent probability of exceedance within 50 years. Locations were identified where liquefaction risk is high, i.e. pipeline or facilities in sandy, saturated soils and within zones of high PGA potential within the two-percent probability of exceedance over a 50-year period. These risks were assessed by comparing pipeline alignments with USGS earthquake hazard maps, as well as NRCS soils maps and field descriptions of soils, and by identifying locations where shallow soils would most likely be saturated. Locations along the alignments with high likelihoods of saturation were identified from the Groundwater Resources Technical Report (MWH 2010).

2.4.3 Unstable Slope Impacts

Geologic hazards were identified where possible during the field survey. Potential hazards include unstable slopes, rockfall, and landslides. Potential hazard indicators on the ground surface have been documented in this field survey. During the field survey, the geologic units mapped by the USGS and others were verified at outcrops along the alignment. In general the mapped units correlated with the rock observed in the field. Rock characteristics were described using the Classification of Rocks and Description of Physical Properties system found in the U.S. Bureau of Reclamation's Engineering Geology Field Manual (USBR 1998). The properties identified included the formation name, lithologic description, hardness, weathering, alteration, strength, color, texture, bedding orientation, discontinuities (faults, joints, sheering, etc.), and a summary description. Where feasible and applicable, rock-mass field characterization was performed using the Geologic Strength Index (BEGE 1998).

2.4.4 Subsidence, Expansion, or Collapsible Soils Impacts

During the field survey, the soil types encountered in the field were compared to the available mapped soil descriptions. The mapped soil descriptions were based on the National Cooperative Soil Survey, operated by the Natural Resource Conservation Service (NRCS). Field soil descriptions were prepared using the Unified Soil Classification System (USCS) method (ASTM 2000, 2006) and are consistent with the U.S. Bureau of Reclamation's Engineering Geology Field Manual. Soil characteristics, including grain size and distribution, color, plasticity, toughness, consistency, angularity, cementation, and dilatancy were estimated and recorded. Characterization occurred along each alignment at major changes in soil or rock types and at important pipeline feature locations, such as pump stations and surge tanks.

Potential hazards identified during characterization of rock and soil included expansive rock and soil, collapsible soils, and subsidence caused by dissolution of minerals (most notably gypsum) or by overpumping of groundwater. There are some indicators that can be identified in the field for expansive and collapsible soils, but the presence of a hazard at the pipeline foundation level is only identifiable with drilling or trenching. In the case of this survey, potential hazard indicators on the ground surface have been documented. The characteristics for potential subsidence, including the presence of gypsum and soil fissures, were noted if observed. The characteristics of potentially expansive soils, primarily the presence of plastic clays and desiccated soils, also were observed and recorded. Potentially collapsible soils were identified where loosely compacted deposits were observed, most probably occurring in alluvial fans or windblown deposits such as loess.

2.4.5 Geologic Hazards to Human Health and Safety Impacts

Locations where loose rock on steep slopes overlying the alignment and unstable slopes that could be affected by pipeline trench excavation or blasting, were noted.

2.4.6 Impacts on Important Structures or Mineral Resources

The presence of buildings and other structures (such as wells and underground utilities) may be impacted by pipeline construction. The locations of structures within approximately 1,000 feet of each alignment were recorded where possible during the field survey. Common features that are unlikely to be disrupted by pipeline construction or operation, such as roads and telephone poles were not recorded unless they were determined to lie directly within the trench path. Road crossings were not noted because these would be repaired as necessary.

The nature and locations of mineral resources, including gravel pits and stone quarries, were noted and recorded if they were within approximately 1,000 feet of the alignments.

2.4.7 Borrow and Spoil Impacts

Potential borrow sources and spoil placement areas were identified along each alignment alternative. Suitable borrow (e.g. existing gravel or sand pits) and spoil locations (e.g. existing spoil sites, spent gravel pits, etc.) were identified if the locations were of sufficient size to be worthwhile for extraction or disposal of materials, had good access to the alignment, and were within about 15 minutes travel time of the alignment. The preliminary inspection included a general description of the primary materials, accessibility, dimensions of area considered, proximity to pipeline proximity to manmade features and any other characteristics that could be relevant to site use. The primary criteria for identifying suitable borrow materials included that most of the materials are non-angular, are generally 1-inch or less in diameter, and have relatively low percentages of silt or clay. These parameters may be modified as circumstances require during design and construction but were used for initial screening of borrow sites.

Chapter 3
Affected Environment (Baseline Conditions)

3.1 Impact Area

3.1.1 Regional Geology

Based on characteristic landforms, North America has been divided into areas called physiographic provinces, with substantial transition zones (zones at boundaries that share characteristics of the adjoining provinces) occurring in some places. The proposed LPP alignment alternatives extend from Lake Powell (near Page, Arizona) to St. George, Utah, and the CVP Alternative alignment extends from the Hurricane Cliffs to Cedar City, Utah. The LPP and CVP alignments are planned to be constructed through two physiographic provinces: approximately 78 percent of the pipeline is proposed to be located in the Colorado Plateau Province and the remaining 22 percent is proposed to be located in the transition zone between the Colorado Plateau and the Basin and Range provinces. For a more detailed description of the regional geology of this area, see TM 5.11 Geological, Geotechnical, and Foundation Conditions (MWH 2009a).

The Colorado Plateau province is generally characterized by a thick sequence of largely undeformed, nearly flat-lying sedimentary rocks. The Colorado Plateau is occasionally interrupted by large-scale northerly-trending structural uplifts or basins (folds). The limbs of some of these folds are locally steep (40 degrees to vertical) but relatively narrow (a few miles). The narrow folds are typically monoclines, characterized by all rocks dipping steeply in one direction, and then flattening out east and west on either side. In general, the monocline folds have resulted from the propagation of deep basement reverse faults that offset deep rock units and deform the overlying sedimentary layers. Active faults in the Colorado Plateau are relatively rare at the surface although they are abundant at depth in older rocks, as exposed in the Grand Canyon part of the Colorado Plateau and specifically at the Cockscomb and the Sevier fault near the Coral Pink Sand Dunes State Park.

The boundary between the Colorado Plateau and the Great Basin is not a single line but instead is a zone up to 62 miles wide, known as a transition zone, in which faults become more abundant and larger farther to the west. The transition zone extends from the Hurricane fault zone at the town of Hurricane westward 30 to 50 miles to the Gunlock fault zone at Gunlock State Park, Utah. The Colorado Plateau proper is generally considered to lie east of the Hurricane Cliffs and the Great Basin proper lies west of Gunlock. The LPP is proposed to enter and cross into this transition zone at the proposed Hurricane Cliffs Hydropower (HCH) facility. The CVP crosses from the Colorado Plateau into the transition zone near the town of La Verkin, Utah.

3.1.2 Area of Potential Effect

The area of potential effect for Geology and Soil Resources includes a corridor encompassing both sides of each of the alignments identified and described in Sections 1.2.1 (South Alternative), 1.2.2 (Existing Highway Alternative), and 1.2.3 (Southeast Corner Alternative). The corridor extended 200 feet on either side of each alternative alignment, and 1,000 feet on each side of each alignment for evaluating potential impacts on important structures and mineral resources.

The Transmission Line Alternatives described in Section 1.2.4 were not included in the Geology and Soil Resources Study Report because these alternatives would not materially affect geology and soils resources.

3.2 Overview of Baseline Conditions

3.2.1 Lake Powell Pipeline

3.2.1.1 Fault Movement

The fault crossings evaluated by FWLA for the LPP section of the pipeline are summarized in Table 3-1. Figures showing the locations of the crossings relative to the pipeline are included in the FWLA report. The fault crossings evaluated to be of potentially high relevance for the LPP section of the pipeline were the Sevier fault and the West Grass Valley fault. The Sevier fault crosses the Highway, South and Southeast Corner alternatives of the LPP. The Sevier fault hazard was designated as potentially high relevance by FWLA based on evidence of Quaternary displacement and the presence of a 3-4 foot scarp just south of the Highway alternative alignment and the displacement of 5-6 feet of alluvium near the South Alternative. The West Grass Valley fault hazard was designated as potentially high relevance based on displacement of approximately the 1 million year-old Grass Valley Basalt and the potential for reactivation of the fault because of its proximity to the main trace of the Hurricane fault. These fault crossings are not located near populated areas, decreasing the potential risk of impacts associated with a pipeline rupture.

3.2.1.2 Seismic Activity

Review of USGS seismic hazard maps shows that the LPP alternatives lie within zones of low to moderate potential seismic activity (0.1 to 0.4 gravity Peak Ground Acceleration) with a two-percent probability of exceedance over a 50-year period.

3.2.1.3 Unstable Slopes

Rocks along the LPP alternatives alignments are primarily sedimentary but include some basalt. Sedimentary rocks include sandstone, siltstone, limestone, shale, and evaporites. Sandstone from the Navajo, Entrada, Page, and Carmel formations is the most common rock type in the eastern part of the LPP alternatives whereas siltstone, limestone, shale, and other sedimentary rocks of the Moenkopi, Chinle, and Kaibab formations are more common further westward. Navajo Sandstone re-appears west of the Hurricane Fault Zone due to westward downthrown displacement. Basalt outcrops are present primarily near the end of the LPP alternatives and in the section from the bottom of the Hurricane Cliffs to Sand Hollow Reservoir.

The rock characteristics observed in the field were compared to existing geologic maps. The rock characteristics observed during the field survey are included in Table 3-2. The locations of survey points are shown on Figures 3-1 and 3-2.

Potential geologic hazards exist along the proposed LPP alternatives. During the field survey, where potential hazard indicators were observed, the area was noted. Upon completing the field survey, the data was extrapolated between survey points using the geologic maps, soil maps and, where available (Washington and Kane Counties, Utah), existing hazard maps. The hazards were separated into ‘rock’ and ‘soil’ categories.

Table 3-1
Lake Powell Pipeline
Fault Intersection Assessment

Fault Name	Alignment	Station Range	Rupture Assessment	Urban development	Preliminary Impact Risk	Remarks
Glen Canyon City fault	HWY	820 + 00	Not significant	No	Low	
East Kaibab fault – Cockscomb	HWY	1729 + 20	Not significant	No	Low	
Central Kaibab fault	HWY	2270 + 00	Low significance	No	Low	
West Kaibab fault	HWY	2570 + 00 and 2579 + 00	Low significance	No	Low	Fault locations inferred
	HWY ALT	2600+00	Low significance	No	Low	Fault location inferred; possible splay at 2566+30
Paunsaugunt fault	HWY	2950 + 00	Low significance	Yes	Low	Fault locations inferred
	South	3030+00 to 3060+00	Low significance	No	Low	Fault locations inferred
	South - Penstock Alt East	170+00	Low significance	No	Low	Fault locations inferred
	South - Penstock Alt Middle	51+00	Low significance	No	Low	Fault locations inferred
Johnson Canyon fault	HWY	3250 + 00 to 3300 + 00	Not significant	No	Low	
	South	3360 + 00	Not significant	No	Low	
Quikwater fault	South	4300 + 00	Not significant	No	Low	
Sevier fault (N. Toroweap)	HWY	4704 + 10	High significance	No	Low	
	South	4985 + 35	High significance	No	Low	
Short Creek fault	HWY	5920 + 00 to 5940 + 00	Not significant	No	Low	
West Grass Valley fault	LPP Hydro	50 + 00	High significance	Yes	High	Upslope of community
	LPP Sand Hollow West Tunnel Alt	44+00	High significance	No	Low	Avoids community
Remnants Basalt faults	LPP Hydro	76 + 00	Not significant	No	Low	
	LPP Hydro	110 + 00	Not significant	No	Low	
Western Sand Mountain fault	LPP Hydro	200 + 00	Not significant	No	Low	

Table 3-2
Lake Powell Pipeline
Field Survey of Rock Characteristics

Station	Northing	Easting	Symbol	Formation	Lithology	Hardness	Weathering	Alteration	Strength	Color	Texture
Lake Powell Water Conveyance System											
4+00	4088436.3N	456406.9E	Jn	Navajo Sandstone	sandstone	H/MH	M	SA	S/MS	red, pink, white	MG
45+00	4088382.4N	455423.4E	Jn	Navajo Sandstone	sandstone	H/MH	M	SA	S/MS	red, pink, white	MG
50+00	4088538.9N	455464.5E	Jn/Jc Contact	Carmel Formation	dark brown weathered shale	M/S	MS	MA	MS/W	white, tan, maroon	A/FG
50+00	4088538.9N	455464.5E	Jn/Jc Contact	Navajo Sandstone	red sandstone	H/MH	M	SA	S/MS	red, pink, white	MG
85+00	4089350.3N	454931.6E	Jc	Carmel Formation	dark red/ brown sandstone	M/S	MS	MA	MS/W	white, tan, maroon	A/FG
200+00	4092583.3N	453610.5E	Je	Entrada Sandstone	cross-bedded sandstone	MH	M	SA	MS	gray, tan, white	FG
880+00	4104734.9N	438028.4E	Jpt	Thousand Pockets Tongue of the Page Sandstone	cross-bedded, poorly cemented sandstone	MH/M	M	SA	MS	tan, gray, pink	CG
1170+00	4106278.5N	429298.5E	Jcu	Upper Unit, Carmel	sandstone over weathered limestone, maroon banding	M/S	MS	MA	MS/W	white, tan, maroon	A/FG
1390+00	4106438.4N	423109.2E	Jcu	Upper Unit, Carmel	sandstone over weathered limestone, maroon banding	M/S	MS	MA	MS/W	white, tan, maroon	A/FG
1685+00 BPS-3 and WCH-1	4109475.4N	414797.6E	Jcu/Je contact	Upper Unit, Carmel	weathered shale	M/S	MS	MA	MS/W	white, tan, maroon	A/FG
1685+00 BPS-3 and WCH-1	4109475.4N	414797.6E	Jcu/Je contact	Entrada Sandstone	sandstone	MH	M	SA	MS	gray, tan, white	FG
1710+00	4109330.3N	414137.5E	Jn	Navajo Sandstone	massive eolian sandstone	H/MH	M	SA	S/MS	red, pink, white	MG
1745+00	4109133.5N	413217.0E	Cockscomb	Cockscomb	Cockscomb Monocline	NA	NA	NA	NA	NA	NA
1770+00	4109988.9N	413240.5E	TRml/Pk contact	Lower Red Member, Moenkopi	red sandstone	VH/H	MS	SA	VS/S	tan, brown, red	FG/MG/CG
1770+00	4109988.9N	413240.5E	TRml/Pk contact	Kaibab	limestone	VH	M	MA	VS	tan, gray	MG
1905+00	4113985.8N	413682.5E	TRmm	Middle Red Member, Moenkopi	sandstone/ siltstone	S/VS	VS	MA/HA	W/VW	red, brown, gray, white, green	FG
1935+00 BPS-4	4114806.4N	413463.3E	TRml/TRmt contact	Lower Red Member, Moenkopi	red sandstone/ shale	VH/H	MS	SA	VS/S	tan, brown, red	FG/MG/CG
1935+00 BPS-4	4114806.4N	413463.3E	TRml/TRmt contact	Timpoweap Member, Moenkopi	yellow limestone	VH	F/VS	F	ES	tan, yellow, brown	FG
1980+00	4115691.4N	412914.2E	TRmt	Timpoweap Member, Moenkopi	limestone	H	S/M	SA/MA	VS	tan, gray	FG
2059+00	4115183.8N	410520.4E	TRml	Lower Red Member, Moenkopi	angular, platy, broken red shale	S/VS	VS	CA	W/VW	red, brown, white, green	A

Table 3-2
Lake Powell Pipeline
Field Survey of Rock Characteristics

Station	Northing	Easting	Symbol	Formation	Lithology	Hardness	Weathering	Alteration	Strength	Color	Texture
2060+00	4115140.4N	410453.6E	TRmt	Timpoweap member, Moenkopi	limestone/ sandstone	H	S/M	SA/MA	VS	tan, gray	FG
2270+00	4111654.2N	405237.7E	TRmt	Timpoweap Member, Moenkopi	limestone/ sandstone	H	S/M	SA/MA	VS	tan, gray	FG
2350+00	4109960.8N	403387.7E	TRmt	Timpoweap Member, Moenkopi	massive dolomite	H	M/MS	SA	S	tan	A/FG
2400+00	4108881.9N	402026.2E	TRml	Lower Red Member, Moenkopi	thin platy sandstone with some shale	VH/H	MS	SA	VS/S	tan, brown, red	FG/MG/CG
Lake Powell Water Conveyance System, Alternative High Point Regulating Tank 2 Alignment											
2566+30	4105766N	398917E	TRml/TRmm contact	Middle Red Member, Moenkopi	siltstone	S	VS	MA	W/VW	red, brown	FG
2674+20 HPRT-2 Alt	4102952N	397331E	TRmm	Middle Red Member, Moenkopi	siltstone	S	VS	MA	W/VW	red, brown	FG
2915+40	4099966N	391090E	TRmm	Middle Red Member, Moenkopi	siltstone	S	VS	MA	W/VW	red, brown	FG
Lake Powell Hydro System, Alternative High Point Regulating Tank 2 Alignment											
2736+60 HS-1 Alt	4101494N	396146E	TRmm	Middle Red Member, Moenkopi	siltstone	S	VS	MA	W/VW	red, brown	FG
2800+80	4100625N	394468E	TRmm	Middle Red Member, Moenkopi	siltstone	S	VS	MA	W/VW	red, brown	FG
Lake Powell Hydro System											
5950+00	4093084.5N	324388.0E	JTRm	Moenave Sandstone	sandstone/ siltstone	MH	M	SA	S/MS	red, brown, white	FG
6270+00	4096842.1N	317795.3E	TRcs	Shinarump Member, Chinle	sandstone and conglomerate	MH	M	F/SA	VS/S	tan, yellow, gray	MG/CG
6970+00	4100838.7N	297842.5E	TRmv	Virgin Limestone	limestone boulders	H/MH	VS/S	SA	S	white, gray, tan, green	FG
6990+00	4101331.4N	297731.9E	Qa	Alluvium	large boulders	NA	NA	NA	NA	NA	NA
7030+00	4102429.5N	297892.5E	TRmv/TRml contact	Virgin Limestone	limestone	H/MH	VS/S	SA	S	white, gray, tan, green	FG
7030+00	4102429.5N	297892.5E	TRmv/TRml contact	Lower Red Member, Moenkopi	red shale and sandstone	VH/H	MS	SA	VS/S	tan, brown, red	FG/MG/CG
Hydro System-Existing Highway Alternative											
3670+00	4096916.5N	367886.3E	TRcs	Shinarump Member, Chinle	sandstone/ conglomerate	MH	M	F/SA	VS/S	tan, yellow, gray	MG/CG
3685+00	4096532.3N	367859.7E	TRcs	Shinarump Member, Chinle	sandstone/ conglomerate	MH	M	F/SA	VS/S	tan, yellow, gray	MG/CG
3750+00	4094829.5N	367280.7e	TRm	Lower or Middle Red Member, Moenkopi	sandstone and shale	VH/H	MS	SA	VS/S	tan, brown, red	FG/MG/CG

Table 3-2
Lake Powell Pipeline
Field Survey of Rock Characteristics

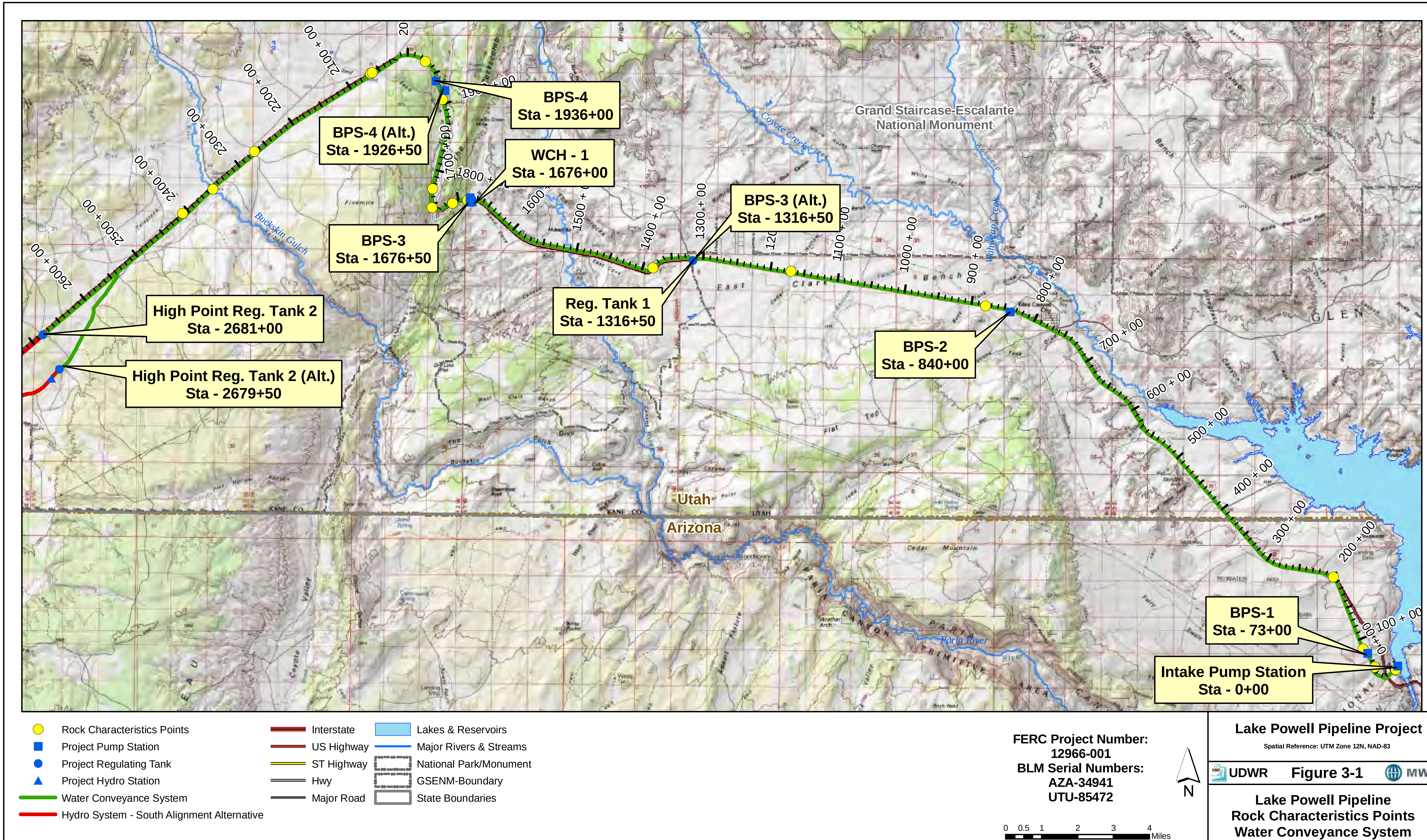
Station	Northing	Easting	Symbol	Formation	Lithology	Hardness	Weathering	Alteration	Strength	Color	Texture
4200+00	4086685.0N	359216.7E	TRmm	Middle Red Member, Moenkopi	weathered shale	S/VS	VS	MA/HA	W/VW	red, brown, gray, white, green	FG
5110+00	4082753.1N	332822.3E	TRcp	Petrified Forest Member, Chinle	claystone/ siltstone with gypsum	M/S	VS	HA	W	red, purple, tan	A/FG
Hydro System-South Alternative											
3000+00	4099328.2N	388045.3E	TRcs	Shinarump Member, Chinle	med to coarse grained sandstone with conglomerate layer	MH	M	F/SA	VS/S	tan, yellow, gray	MG/CG
3010+00	4099306.8N	388268.3E	TRcs/TRmu contact	Shinarump Member, Chinle	sandstone and conglomerate	MH	M	F/SA	VS/S	tan, yellow, gray	MG/CG
3010+00	4099306.8N	388268.3E	TRcs/TRmu contact	Upper Red Member, Moenkopi	red shale	S/VS	VS	MA/HA	W/VW	red, brown, gray, white, green	FG
3552+00	4088851.4N	377181.9E	TRm	Lower or Middle Red Member, Moenkopi	hard sandstone and some platy siltstone	VH/H	MS	SA	VS/S	tan, brown, red	FG/MG/CG
3755+00	4085999.5N	372353.0E	TRm	Lower or Middle Red Member, Moenkopi	red sandstone	VH/H	MS	SA	VS/S	tan, brown, red	FG/MG/CG
3880+00	4083471.9N	369665.4E	TRm	Lower or Middle Red Member, Moenkopi	red sandstone	VH/H	MS	SA	VS/S	tan, brown, red	FG/MG/CG
4005+00	4081417.2N	367931.5E	TRmt/PK	Timpoweap Member, Moenkopi or Kaibab	limestone	VH	M	MA	VS	tan, gray	MG
4060+00	4079350.1N	365921.2E	TRmt/TRmt/Pkh	Virgin Limestone, Timpoweap, or Harrisburg Member, Kaibab	massive gray limestone with chert nodules	VH	M	MA	VS	tan, gray	MG
4150+00	4077276.4N	365367.0E	TRmt/Pk	Timpoweap Member, Moenkopi or Kaibab	limestone	VH	M	MA	VS	tan, gray	MG
4180+00	4077021.0N	364591.1E	Pkh	Harrisburg Member, Kaibab	limestone/ sandstone	M	M	SA	MS	tan	FG
4190+00	4077113.7N	364364.7E	Pk	Kaibab	sandstone/ limestone	M	M	SA	MS	tan	FG
4200+00	4077304.7N	363905.7E	Pk	Kaibab	red and yellow limestone/ sandstone outcrop	M	M	SA	MS	tan	FG
4250+00	4077316.2N	362648.4E	Pk	Kaibab	linestone outcrop	M	M	SA	MS	tan	FG
4275+00	4077348.2N	361248.5E	Pkh	Harrisburg Member, Kaibab	limestone/ dolomite	M	M	SA	MS	tan	FG
4418+00	4076828.0N	357564.7E	Pk	Kaibab	limestone	M	M	SA	MS	tan	FG
4420+00	4076890.8N	357558.9E	Pkh	Harrisburg Member, Kaibab	cherty, fossiliferous limestone, weathered, blocky	M	M	SA	MS	tan	FG

Table 3-2
Lake Powell Pipeline
Field Survey of Rock Characteristics

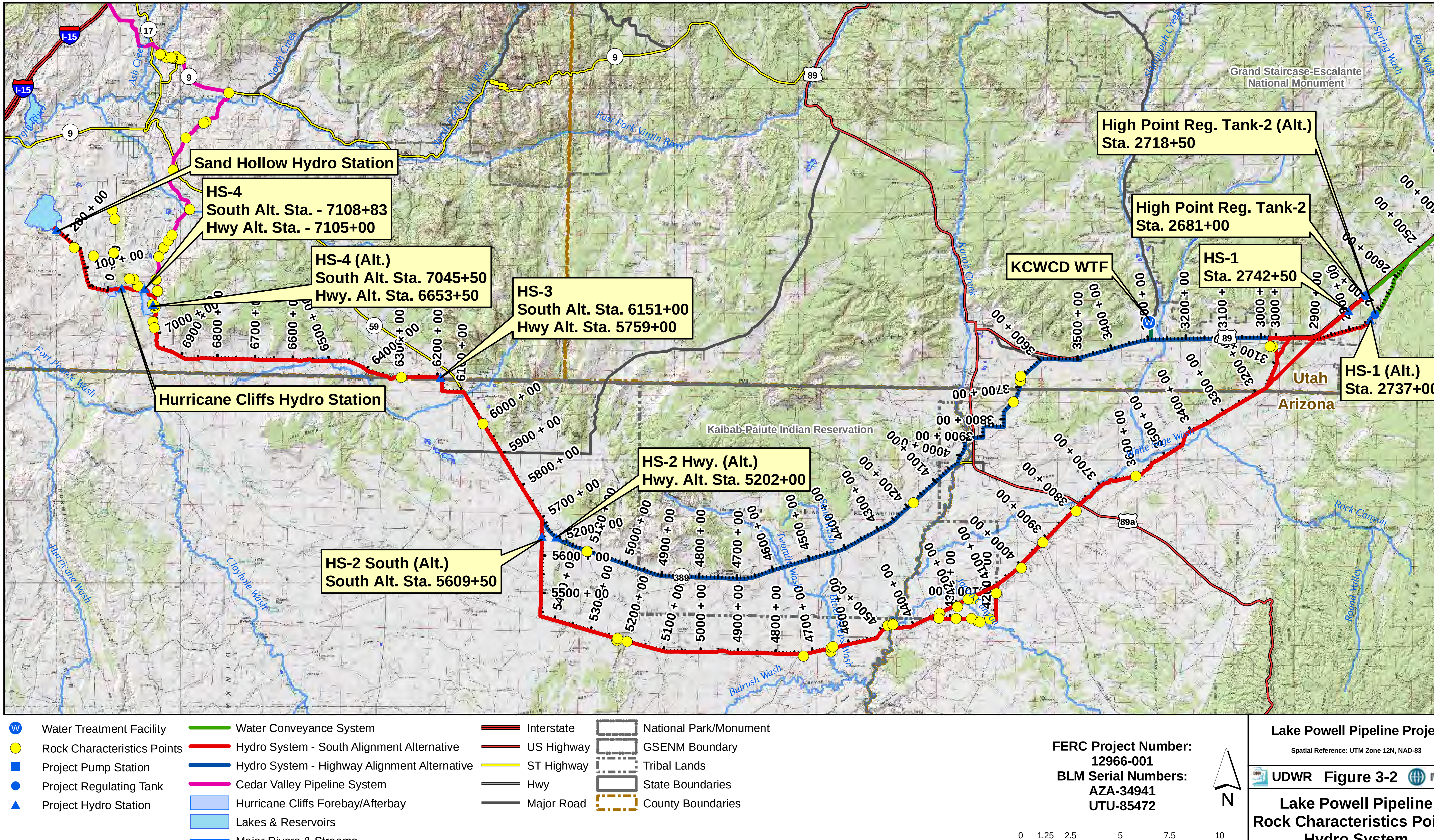
Station	Northing	Easting	Symbol	Formation	Lithology	Hardness	Weathering	Alteration	Strength	Color	Texture
4440+00	4076753.0N	357120.3E	TRml	Lower Red Member, Moenkopi	red sandstone	VH/H	MS	SA	VS/S	tan, brown, red	FG/MG/CG
4602+00	4075023.2N	352695.2E	Pk	Kaibab	rockfall hazard	M	M	SA	MS	tan	FG
4608+00	4074951.6N	352567.7E	Pk	Harrisburg Member or Fossil Mountain Member, Kaibab	cherty, fossiliferous limestone, weathered, blocky	M	M	SA	MS	tan	FG
4610+00	4074647.9N	352525.5E	TRml over Pkh	Lower Red Member, Moenkopi	red sandstone	H/MH	S/M	SA	S	light red	CG
4610+00	4074647.9N	352525.5E	TRml over Pkh	Harrisburg Member, Kaibab	massive limestone	VH	M	MA	VS	tan, gray	MG
4680+00	4074279.1N	350329.9E	TRml	Lower Red Member, Moenkopi	thin platy sandstone	H/MH	S/M	SA	S	light red	CG
5155+00	4075466.2N	336076.4E	TRcs over TRmu	Shinarump Member, Chinle	sandstone and conglomerate	MH	M	F/SA	VS/S	tan, yellow, gray	MG/CG
5155+00	4075466.2N	336076.4E	TRcs over TRmu	Upper Red Member, Moenkopi	red shale	S/VS	VS	MA/HA	W/VW	red, brown, gray, white, green	FG
5170+00	4075549.3N	335216.8E	TRcs	Shinarump Member, Chinle	coarse grained sandstone	MH	M	F/SA	VS/S	tan, yellow, gray	MG/CG
5170+00	4075719.8N	335269.5E	TRcs	Shinarump Member, Chinle	medium grained sandstone	MH	M	F/SA	VS/S	tan, yellow, gray	MG/CG
Hydro System-South Alternative, Middle Penstock											
	4100006N	389648E	TRms	Shnabkaib Member, Moenkopi	gypsiferous siltstone	S	VS	MA	W/VW	red, brown, pale tan	FG
17+60	4099522N	389318E	TRms	Shnabkaib Member, Moenkopi	gypsiferous siltstone	S	VS	MA	W/VW	red, brown, pale tan	FG
Hydro System-South Alternative, East Penstock											
02+00	4100349N	392183E	TRmm	Middle Red Member, Moenkopi	siltstone/sandstone	S	VS	MA	VW	red, brown	FG/MG
22+00	4099913N	391736E	TRmm	Middle Red Member, Moenkopi	siltstone/sandstone	S	VS	MA	VW	red, brown	FG/MG
89+75	4098474N	390243E	TRmm	Middle Red Member, Moenkopi	siltstone/sandstone	S	VS	MA	VW	red, brown	FG/MG
Hydro System-Southeast Corner Alignment Alternative											
4100+00	4078902.9N	364032.8E	TRml	Lower Red Member, Moenkopi	red sandstone	VH/H	MS	SA	VS/S	tan, brown, red	FG/MG/CG
4130+00	4078888.3N	363628.8E	TRml	Lower Red Member, Moenkopi	red sandstone with white/ yellow weathered surface	VH/H	MS	SA	VS/S	tan, brown, red	FG/MG/CG

Table 3-2
Lake Powell Pipeline
Field Survey of Rock Characteristics

Station	Northing	Easting	Symbol	Formation	Lithology	Hardness	Weathering	Alteration	Strength	Color	Texture
4160+00	4078270.3N	362765.1E	TRml	Lower Red Member, Moenkopi	red sandstone	VH/H	MS	SA	VS/S	tan, brown, red	FG/MG/CG
4200+00	4077719.2N	361312.3E	Pkh	Harrisburg Member, Kaibab	limestone/ dolomite	M	M	SA	MS	tan	FG
Hurricane Cliffs ORIGINAL Forebay and Afterbay and ORIGINAL Sand Hollow Section of LPP Hydro System											
N Forebay Embankment	4104247.8N	296489.2E	Qb	Basalt	basalt boulders	VH	S	SA	VS	black, cream	A
Between Forebay and Afterbay	4104765.5N	296169.9E	Pk/TRmt	Kaibab Limestone/ Timpoweap	massive limestone	H	S	MA	ES	tan	FG
Hurricane Cliffs	4104808.6N	295824.5E	Pk	Kaibab	massive, cherty, fossiliferous limestone	VH	M	MA	VS	tan, gray	MG
40+00 N of Afterbay	4106914.1N	294554.3E	Qb	Basalt	basalt flow	VH	S	SA	VS	black, cream	A
Sand Hollow Pump Storage Alignment Section of LPP Hydro System											
41+80	4104099N	292795E	Qb/Jn	Basalt/Navajo Sandstone	basalt boulders overlying sandstone and sand	VH/MH	F/M	F/MA	VS/MS	black, dark gray/red, pink	A/MG
84+80	4105213N	292285E	Qb	Basalt	basalt boulders in sand	VH	VS	F	VS	dark gray	A
90+80	4105392N	292250E	Qb	Basalt	basalt boulders (E. of alignment)	VH	F	F	VS	black	A
195+90	4108056	290736	Jn	Navajo Sandstone	sandstone outcrop in gulley, overlain by sand	M	MS	SA	MS	red, pink	MG



BPS-4
Sta - 1936+00
BPS-4 (Alt.)
Sta - 1926+50
WCH - 1
Sta - 1676+00
BPS-3
Sta - 1676+50
BPS-3 (Alt.)
Sta - 1316+50
Reg. Tank 1
Sta - 1316+50
BPS-2
Sta - 840+00
High Point Reg. Tank 2
Sta - 2681+00
High Point Reg. Tank 2 (Alt.)
Sta - 2679+50
BPS-1
Sta - 73+00
Intake Pump Station
Sta - 0+00
Grand Staircase-Escalante
National Monument
Utah
Arizona
Rock Characteristics Points
Project Pump Station
Project Regulating Tank
Project Hydro Station
Water Conveyance System
Hydro System - South Alignment Alternative
Interstate
US Highway
ST Highway
Hwy
Major Road
Lakes & Reservoirs
Major Rivers & Streams
National Park/Monument
GSENM-Boundary
State Boundaries
FERC Project Number:
12966-001
BLM Serial Numbers:
AZA-34941
UTU-85472
0 0.5 1 2 3 4
Miles
N
Lake Powell Pipeline Project
Spatial Reference: UTM Zone 12N, NAD-83
UDWR
Figure 3-1
MWH
Lake Powell Pipeline
Rock Characteristics Points
Water Conveyance System



Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR Figure 3-2 MWH

Lake Powell Pipeline
Rock Characteristics Points
Hydro System

The geology and/or rock hazards are shown on Figures 3-3 and 3-4, and include the presence of gypsum in rock, expansive clay bedrock, rockfall, landslides, unstable slopes and steeply dipping bedrock. Areas where geologic hazards were not identified in the field were designated as low risk. However, as-yet unidentified rock hazards may still be present. Rock hazards have been broken up into segments where they are likely to exist along the alignment, and are shown in Tables 3-3 through 3-6 below.

Table 3-3
Lake Powell Water Conveyance System Rock Hazards

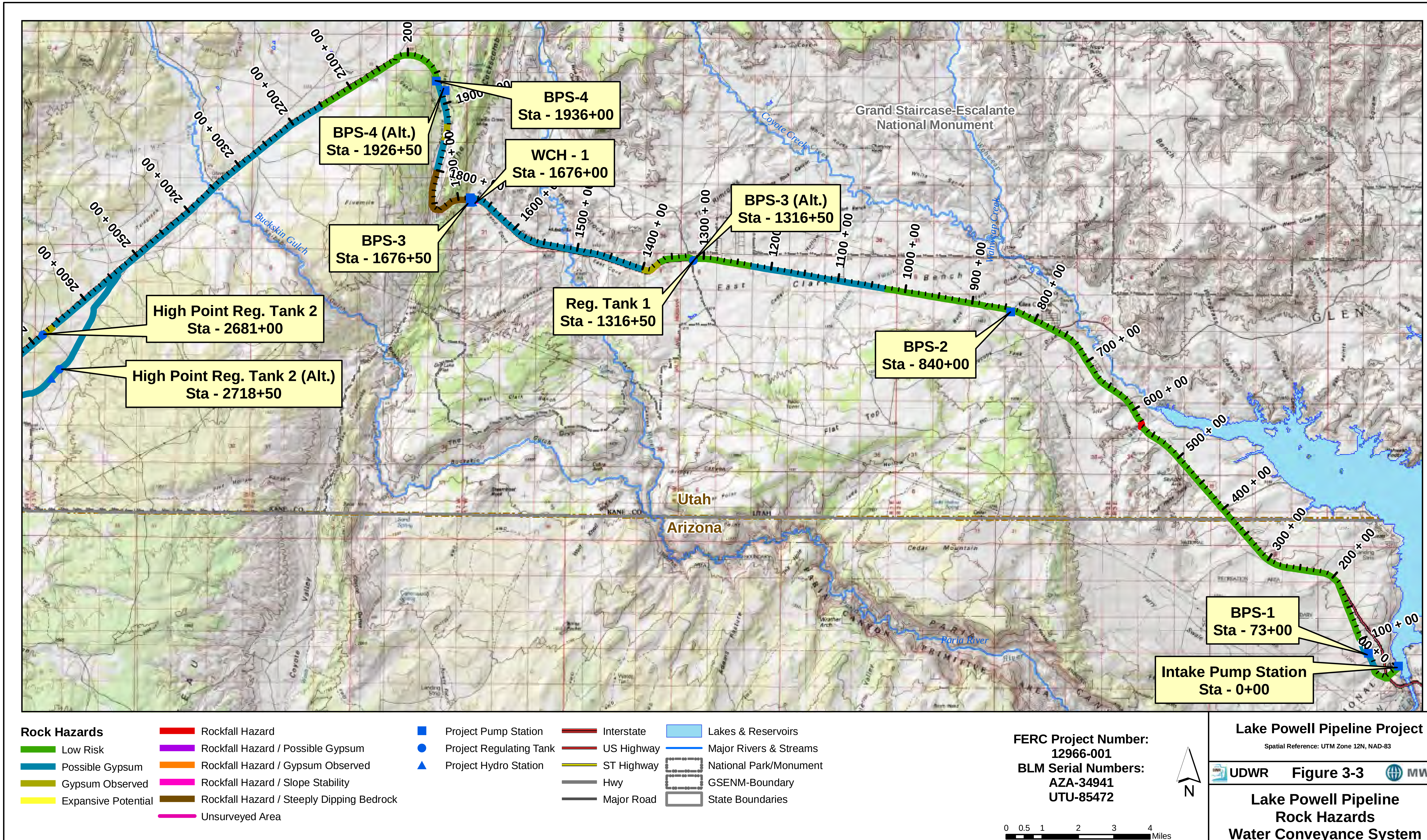
From Station:	To Station:	Description
50+00 WCS	100+00 WCS	possible gypsum
570+00 WCS	580+00 WCS	rockfall hazard
1030+00 WCS	1230+00 WCS	possible gypsum
1370+00 WCS	1400+00 WCS	gypsum observed
1400+00 WCS	1685+00 WCS	possible gypsum
1685+00 WCS	1800+00 WCS	rockfall hazard and steeply dipping bedrock
1800+00 WCS	1845+00 WCS	possible gypsum
1845+00 WCS	1870+00 WCS	gypsum observed
1870+00 WCS	1935+00 WCS	possible gypsum
2150+00 WCS	2660+00 WCS	possible gypsum
2660+00 WCS	2680+00 WCS	gypsum observed

Table 3-4
Hydro System-Highway Alternative Rock Hazards

From Station:	To Station:	Description
2980+00 HS	3700+00 HWY	expansive potential
3700+00 HWY	3750+00 HWY	rockfall hazard
3850+00 HWY	3960+00 HWY	possible gypsum
3960+00 HWY	4020+00 HWY	gypsum observed
4020+00 HWY	4130+00 HWY	possible gypsum
4130+00 HWY	4700+00 HWY	gypsum observed
4700+00 HWY	4800+00 HWY	possible gypsum
4800+00 HWY	5100+00 HWY	expansive potential
5100+00 HWY	5120+00 HWY	gypsum observed

Table 3-5 Hydro System-South Alternative Rock Hazards		
From Station:	**To Station:**	**Description**
2980+00 HS	2990+00 SOUTH	expansive potential
2990+00 SOUTH	3015+00 SOUTH	rockfall hazard
3015+00 SOUTH	3200+00 SOUTH	possible gypsum
4165+00 SOUTH	4180+00 SOUTH	rockfall hazard and slope stability
4390+00 SOUTH	4440+00 SOUTH	rockfall hazard and slope stability
4600+00 SOUTH	4610+00 SOUTH	rockfall hazard and slope stability
5000+00 SOUTH	5030+00 SOUTH	possible gypsum
5030+00 SOUTH	5045+00 SOUTH	gypsum observed
5045+00 SOUTH	5152+00 SOUTH	possible gypsum
5152+00 SOUTH	5154+00 SOUTH	rockfall

Table 3-6 Lake Powell Hydro System Rock Hazards		
From Station:	**To Station:**	**Description**
2680+00 WCS	2915+00 HS	possible gypsum
2915+00 HS	2950+00 HS	gypsum observed
2950+00 HS	2980+00 HS	expansive potential
6150+00 HS	6250+00 HS	expansive potential
6290+00 HS	6370+00 HS	rockfall hazard
6370+00 HS	6780+00 HS	possible gypsum
7010+00 HS	7045+00 HS	rockfall hazard



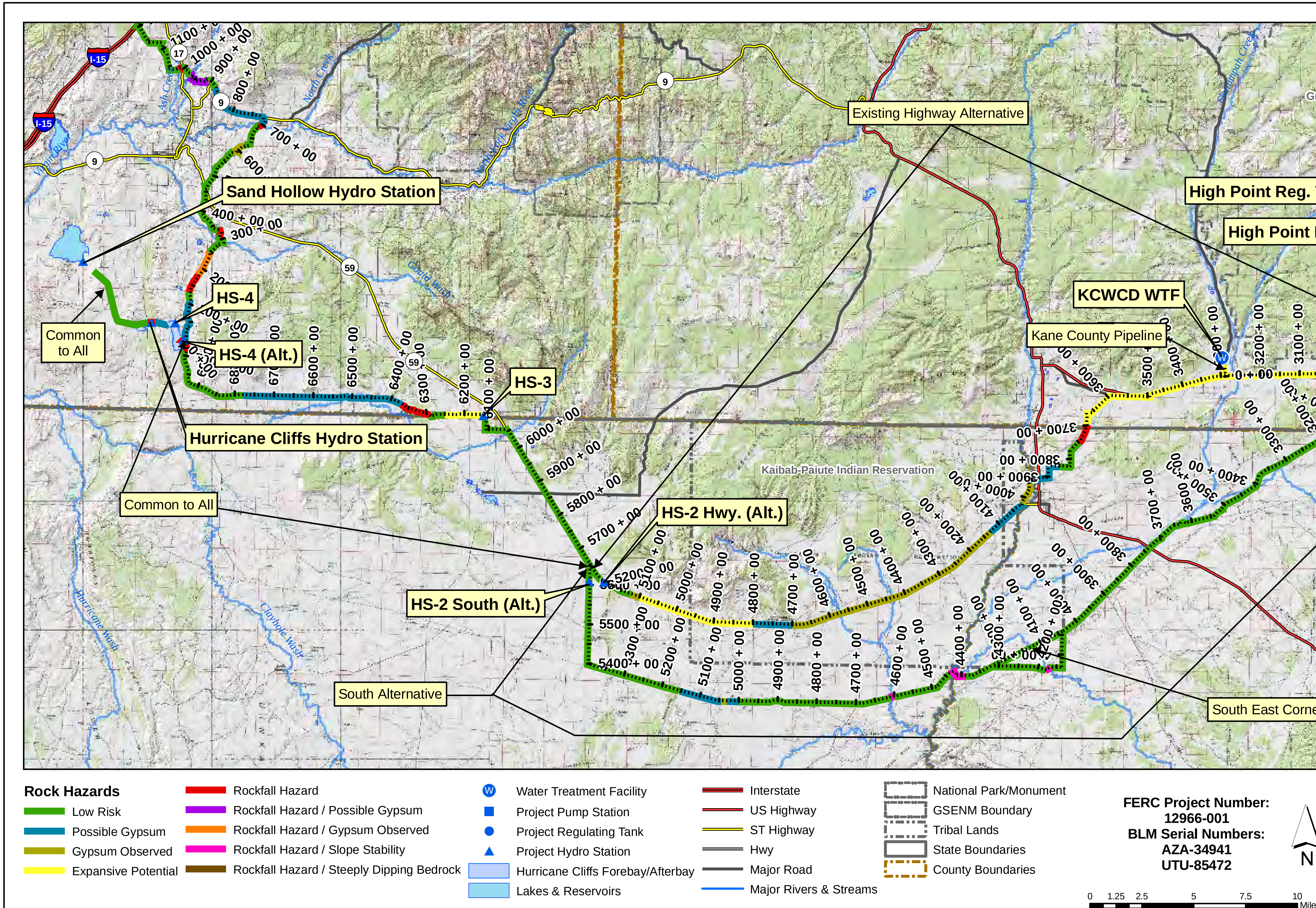
FERC Project Number:
12966-001
BLM Serial Numbers:
AZA-34941
UTU-85472

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR **Figure 3-3** MWH

Lake Powell Pipeline
Rock Hazards
Water Conveyance System



Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR Figure 3-4 MWH

Lake Powell Pipeline
Rock Hazards
Hydro System

3.2.1.4 Subsidence, Expansion, and Collapsible Soils

Soils along the LPP alignments are typically composed of alluvial, eolian and fluvial deposits and terraces. Some soils are weathered-in-place residual soils over shallow sedimentary bedrock. Soils east of the Cockscomb are typically eolian sand derived from the Navajo, Entrada and Page Sandstone formations. Soils over the Carmel Formation are typically weathered shale, limestone and sandstone and the shale typically contains gypsum. Soils along the Highway, South and Southeast Corner alignment alternatives typically consist of clay, silty loam, silty clay loam, or sandy loam. The soils are mostly weathered from the Moenkopi Formation and are shale, sandstone, or limestone derived. Soils in the Shinarump Member of the Chinle Formation consist of coarse sand and gravel weathered from the sandstone and well rounded gravel conglomerate. Soils in the Petrified Forest Member of the Chinle Formation are primarily plastic clays, or occasionally, fine sands. The soil near Sand Hollow Reservoir consists of variable depths of windblown sand derived from weathering of Navajo Sandstone outcrops.

The soil characteristics observed in the field were compared to the NRCS descriptions. The soil characteristics observed during the field survey are provided in Table 3-7. The locations of the field survey points are shown on Figures 3-5 and 3-6.

Potential geologic hazards exist along the proposed LPP alignment alternatives. During the field survey, where potential hazard indicators were observed, the area was noted. Upon completing the field survey, the data was extrapolated between survey points using the geologic maps, soil maps and, where available (Washington and Kane Counties, Utah), existing hazard maps. The hazards were separated into 'rock' and 'soil' categories.

Soil hazards are shown on Figures 3-7 and 3-8 and include the presence of gypsiferous soils and soil with expansive or collapsible potential. Areas where geologic hazards were not identified were designated as low risk. However, as-yet unidentified soil hazards may still be present. Soil hazards have been broken up into segments where they are likely to exist along the alignment, and are shown in Tables 3-8 through 3-11.

Table 3-7
Lake Powell Pipeline
Field Survey of Soil Characteristics

Station	Northing	Easting	Soil Symbol	Soil Name	USCS Class	% Cobble	% Gravel	% C. Sand	% M. Sand	% F. Sand	% Fines	Color	Fines Dilatancy	Toughness	Plasticity	Fines Consistency	Sand/Gravel Angularity	Cementation	Origin
Lake Powell Water Conveyance System																			
54+00	4088618.7N	455367.0E	33	Pagina-Wahweap complex	SP	0	0	0	0	100	0	Red	NA	NA	NA	NA	R	W	derived from Navajo SS
74+50 BPS-1	4089219.9N	455127.5E	33	Pagina-Wahweap complex	SP	0	0	0	0	100	0	Red	NA	NA	NA	NA	R	W	derived from Navajo SS
100+00	4089635.3N	454824.2E	33	Pagina-Wahweap complex	SP	0	0	0	0	100	0	Red	NA	NA	NA	NA	R	W	derived from Navajo SS
550+00	4098818.8N	445524.6E	s342	Rock Outcrop - Moenkopi	SP	0	0	0	50	50	0	Red	NA	NA	NA	NA	R	W	weathered Moenkopi
790+30	4104003N	440509E	s351	Wayneco-Sazi-Rock outcrop-Rizno-Palma-Mespun (most like Mespun soils)	SP	0	TR	TR	10	90	0	Red	NA	NA	NA	NA	R	W	
1315+50 Reg Tank 1	4106795.7N	424793.8E	5138	Nakai-Sheppard complex	SM	0	0	0	0	60	40	Red	NA	NA	NA	NA	R	W	limestone derived, weathered Jcu
1905+00	4113981.0N	413681.6E	5112	Barx-Radnik	SP	0	0	0	0	100	0	Red	NA	NA	NA	NA	R	W	eolian
2030+00	4115584.0N	411334.6E	5037	Barx fine sandy loam	SP	0	0	0	0	100	0	Red	Rapid	Low	Non-Plastic	NA	R	None	alluvium/ eolian
2090+00	4114860.5N	410168.7E	5037	Barx fine sandy loam	SP	0	0	0	0	100	0	Red	Rapid	Low	Non-Plastic	NA	R	None	alluvium/ eolian
2540+00	4106194.0N	399089.9E	5172	Ruinpoint-Barx complex	SC	0	0	0	60	0	40	Red, Brown	NA	NA	NA	NA	SR	W	weathered Moenkopi
2680+00	4103412.6N	395774.4E	5171	Kenzo-Retsabal-Progresso Complex	CL	0	0	0	0	0	100	Pale Tan, Pale Red	Rapid	Low	Low	Hard	NA	None	alluvium from Moenkopi/ Chinle
2741+00 HS-1	4102274.4N	394311.4E	5171	Kenzo-Retsabal-Progresso Complex	CL	0	0	0	0	0	100	Pale Tan, Pale Red	Rapid	Low	Low	Hard	NA	None	weathered Moenkopi
2920+00	4100067.2N	389563.9E	5171	Kenzo-Retsabal-Progresso Complex	CL	0	0	0	0	0	100	Pale Tan, Pale Red	Rapid	Low	Low	Hard	NA	None	alluvium from Moenkopi/ Chinle
Lake Powell Hydro System																			
5880+00	4090724.6N	325815.4E	2	Barx fine sandy loam	SP	0	0	0	0	80	20	Pale Red	Rapid	Low	Low	Firm	R	M	alluvium/ eolian
5950+00	4093084.5N	324388.5E	37	Mido fine sand	SC	0	10	0	10	40	40	Pale Red	Rapid	Low	Medium	Firm	R - SR	W	alluvium/ eolian/ weathered in place ss
6050+00	4095657.7N	322692.3E	38/44	Mido loamy fine sand	SC/CL	0	0	0	0	40 - 60	40 - 60	Brown, Pale Red	Rapid	Low	Medium	Hard	R - SR	M-S	alluvium
6090+00	4095689.7N	321777.7E	44	Palma loamy fine sand	SP	0	0	0	50	50	0	Red	NA	NA	Non-Plastic	NA	SR - R	None	eolian
6148+50	4096810.3N	321103.4E	PAC/44	Palma loamy fine sand	SP	0	0	0	50	50	0	Red	NA	NA	Non-Plastic	NA	SR - R	None	eolian
6210+00	4096810.3N	321103.4E	MFD/50	Mespun Fine Sand/Radnik Fine Sandy Loam	SP	0	5	0	0	95	0	Pale Red	NA	NA	Non-Plastic	NA	R	W	wind-blown sand over Petrified Forest member

Table 3-7
Lake Powell Pipeline
Field Survey of Soil Characteristics

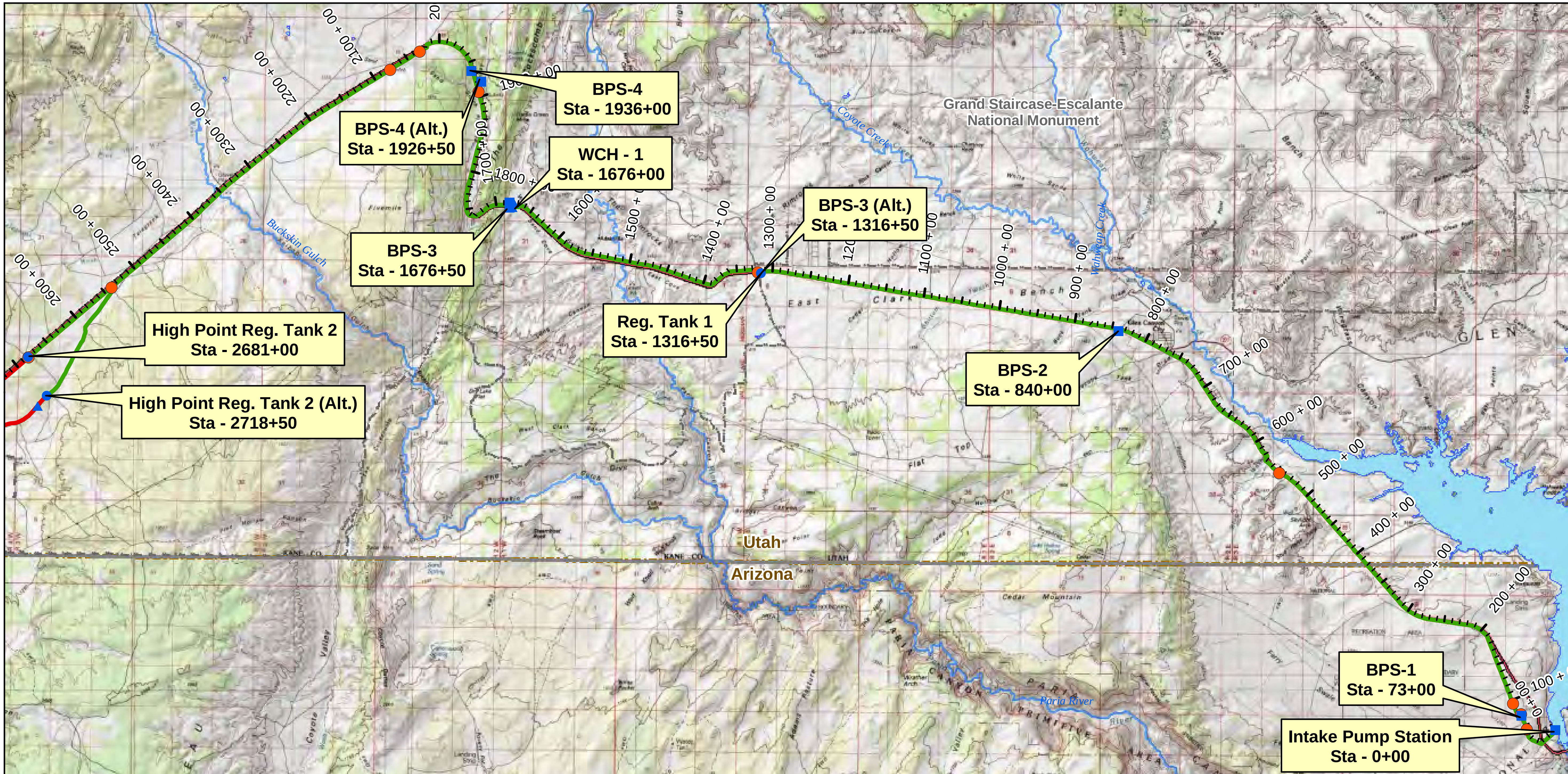
Station	Northing	Easting	Soil Symbol	Soil Name	USCS Class	% Cobble	% Gravel	% C. Sand	% M. Sand	% F. Sand	% Fines	Color	Fines Dilatancy	Toughness	Plasticity	Fines Consistency	Sand/Gravel Angularity	Cementation	Origin
6275+00	4096825.2N	317303.4E	6	Bidonia-Bond Rock outcrop complex	SC	0	0	0	35	35	30	Red, Brown	Rapid	Low	Low to Medium	Firm to Hard	SR - R	W, some caliche	alluvium
6440+00	4098129.9N	312524.9E	NaC	Naplene Silt loam	CH	0	<5	0	0	0	95	Red	Rapid	Low	High	Firm	NA	None	alluvium from Moenkopi
6450+00	4097750.5N	311879.9E	NaC	Naplene Silt loam	CH	0	<5	0	0	0	95	Red	Rapid	Low	High	Firm	NA	W	alluvium from Moenkopi
6550+00	4098207.8N	309105.2E	SH	Schmutz Loam	ML	5	TR	0	0	10	85	Pale Brown	Rapid	Low	Low	Soft	NA	W	old alluvium
6920+00	4099229.1N	298223.6E	SH	Schmutz Loam	ML	5	TR	0	0	10	85	Pale Brown	Rapid	Low	Low	Soft	SR	None	old alluvium
Hydro System-Existing Highway Alternative																			
3130+00	4099907.1N	383222.9E	s8197	Yarts/Palma/ Neville Family - Barx Atchee	SM	0	5	0	0	70	25	Red	Rapid	Low	Non-Plastic	Firm	SA (gravel) R (sand)	None	alluvium from Jm/TRcp
3230+00	4099906.8N	380408.5E	s8197	Yarts/Palma/ Neville Family - Barx Atchee	SM	0	5	0	0	70	25	Red	Rapid	Low	Non-Plastic	Firm	SA (gravel) R (sand)	None	alluvium from Jm/TRcp
3380+00	4099316.1N	376007.0E	s8197	Yarts/Palma/ Neville Family - Barx Atchee	ML	0	0	0	0	0	100	Red	Rapid	Low	Non-Plastic	Soft	NA	None	alluvium
3500+00	4098259.9N	372599.9E	s8197	Yarts/Palma/ Neville Family - Barx Atchee	ML	0	0	0	0	0	100	Red	Rapid	Low	Non-Plastic	Soft	NA	M	eolian or alluvium
3610+00	4098085.9N	369348.3E	s8198	Skos - Rock Outcrop	CL/CH	0	0	0	0	0	100	Red, Brown	unknown	unknown	unknown	unknown	NA	unknown	alluvium
3665+00	4096965.1N	367943.2E	s8197	Yarts/Palma/ Neville Family - Barx Atchee	CL/CH	0	0	0	0	0	100	Red, Brown	unknown	unknown	unknown	unknown	NA	unknown	alluvium
3750+00	4094828.6N	367280.1E	47	Torriorthents	ML, CL	0	0	0	0	5	95	Pale Tan, Gray, Pale Green	Rapid	Low	Non-Plastic	Hard	SR	M	alluvium derived from limestone
3780+00	4093829.7N	366506.6E	16	Glenyon silty clay loam	CH	0	0	0	0	0	100	Red	None	Low	High	Firm	NA	W	alluvium
3820+00	4093022.1N	366573.4E	47	Torriorthents	ML	0	0	0	0	5	95	Pale Tan, Gray, Pale Green	Rapid	Low	Non-Plastic	Hard	SR	M	alluvium derived from limestone
3950+00	4091804.0N	363468.3E	18/19	Jocity loamy fine sand	CH	0	0	0	0	0	100	Pale Red	None	Medium	High	Hard	NA	M	alluvium
4005+00	4090301.9N	362966.3E	15	Gypsiorthids shallow complex	ML	0	0	0	0	30	70	Pale Red	Rapid	Low	Non-Plastic	Hard	R	M	eolian or alluvium
4110+00	4088167.4N	360856.4E	55	Sheppard fine sand	SP	0	0	0	0	90	10	Red	Rapid	Low	Non-plastic	NA	SR	W	alluvium
4280+00	4084773.2N	357085.7E	21	Jocity silty clay loam	CH	0	0	0	0	0	100	Pale Red, Brown	Slow	Low	High	Firm	NA	S	alluvium
4370+00	4083445.0N	354687.5E	10	clayhole loam	ML	0	0	0	0	20	80	Pale Red	Rapid	Low	Non-Plastic	Firm	R	S	alluvium
4420+00	4082686.3N	353141.5E	22	Kinan gravelly loam	SM	0	5	0	65	30	0	Brown, Red	NA	NA	NA	NA	R	M	alluvium
4570+00	4081411.4N	348778.9E	38	Mido loamy fine sand	SP	0	0	0	100	0	0	Pale Red	NA	Low	Non-Plastic	NA	SR	W	alluvium/ eolian
4650+00	4080495.0N	345878.8E	15	Gypsiorthids shallow complex	CH	0	0	0	0	0	100	Pale Red	Rapid	Low	High	Soft	NA	S	weathered TRmm
4695+00	4080623.7N	345201.8E	42	Monue fine sandy loam	SP	0	0	0	50	50	0	Pale Red	Rapid	Low	Non-Plastic	NA	R	W	alluvium from sandstone
4755+00	4080566.6N	343178.8E	20	Jocity silty clay loam	CH	0	0	0	0	0	100	Pale Red	Rapid	Low	High	Firm to Hard	NA	M	clay alluvium
5150+00	4083202.6N	331539.7E	63/9	Torriorthents rock outcrop complex/Campanile clay	CH	5	0	0	0	0	95	Tan, Red, Purple	None	Low	High	Soft	NA	None	weathered in place shale
5202+00 HS-2 Highway	4083915.3N	330234.3E	2	Barx fine sandy loam	SP	0	0	0	0	80	20	Pale Red	Rapid	Low	Low	Firm	R	M	alluvium

Table 3-7
Lake Powell Pipeline
Field Survey of Soil Characteristics

Station	Northing	Easting	Soil Symbol	Soil Name	USCS Class	% Cobble	% Gravel	% C. Sand	% M. Sand	% F. Sand	% Fines	Color	Fines Dilatancy	Toughness	Plasticity	Fines Consistency	Sand/Gravel Angularity	Cementation	Origin
Hydro System-South Alternative																			
3060+00	4097824.0N	388554.0E	s8197	Yarts/Palma/ Neville Family - Barx Atchee	CL/ML	0	0	0	0	0	100	Red	unknown	unknown	unknown	unknown	NA	unknown	alluvium from Upper Red Moenkopi
3130+00	4095892.6N	387619.7E	s8198	Skos - Rock Outcrop	CL/ML	0	0	0	0	0	100	Red	unknown	unknown	unknown	unknown	NA	unknown	rounded gravel from Shinarump. Weathered Upper Red Moenkopi
3190+00	4094912.6N	385927.2E	8	Clayhole silty loam	SM	0	0	0	0	20	80	Pale Red	Rapid	Low	Non-Plastic	Firm	R	M	weathered Moenkopi
3300+00	4093444.0N	383863.7E	47	Torriorthents	CH	0	0	0	0	0	100	Pale Red, Brown	unknown	unknown	unknown	unknown	NA	M	alluvium derived from limestone
3400+00	4091583.7N	381021.4E	19	Jocity silty clay loam	CL	0	0	0	0	0	100	Pale Red	Rapid	Low	High	Firm to Hard	NA	M	partially derived from limestone
3455+00	4090504.4N	379665.3E	23	Klondike sandy clay loam	CH	0	0	0	0	0	100	Red	None to Slow	Low	High	Hard	NA	W	alluvium
3550+00	4088859.5N	377279.6E	19/23	Jocity silty clay loam/Klondike sandy clay loam	CH	0	0	0	0	0	100	Red	None to Slow	Low	High	Hard	NA	M	note chert gravel
3680+00	4087699.4N	374203.4E	19	Jocity silty clay loam	CH	0	0	0	0	0	100	Pale Red	Rapid	Low	High	Hard	NA	M	alluvium, no gravel
4000+00	4081837.8N	368058.2E	10	Clayhole loam	ML	0	20	0	0	5	75	Tan, Pale Brown	Rapid	Low	Non-Plastic	Soft	SA	None	alluvium derived from limestone
4695+00	4074473.5N	350015.5E	47 or 20	Pennell gravelly loam or Jocity silty clay loam	CH	0	TR	0	0	0	100	Pale Red, Brown	None	Low	High	Firm	NA	None	possibly eolian clay
4815+00	4074530.7N	346360.8E	20	Jocity silty clay loam	CH	0	0	0	0	0	100	Pale Red	Rapid	Low	High	Hard	NA	None	clay alluvium
4830+00	4074361.0N	345906.0E	20	Jocity silty clay loam	CH	0	0	0	0	0	100	Pale Red	Rapid	Low	High	Hard	NA	None	clay alluvium
4830+00	4074527.6N	345875.8E	20	Jocity silty clay loam	CH	0	0	0	0	0	100	Pale Red	Rapid	Low	High	Hard	NA	None	clay alluvium
4880+00	4074425.7N	344271.9E	20	Jocity silty clay loam	CH	0	0	0	0	0	100	Pale Red	Rapid	Low	High	Hard	NA	None	clay alluvium
4950+00	4074434.9N	342205.1E	20	Jocity silty clay loam	CH	0	0	0	0	0	100	Pale Red	Rapid	Low	High	Firm to Hard	NA	None	clay alluvium
5020+00	4074510.5N	340196.0E	20	Jocity silty clay loam	CH	0	0	0	0	0	100	Pale Red	Rapid	Low	High	Firm to Hard	NA	None	clay alluvium
5040+00	4074524.4N	339474.9E	20	Jocity silty clay loam	CH	0	0	0	0	0	100	Pale Red	Rapid	Low	High	Firm to Hard	NA	None	white caliche crust
5090+00	4074952.9N	338027.4E	13	Grieta fine sandy loam	ML	0	TR	0	0	0	100	Pale Red	Rapid	Low	Non-Plastic	Hard	NA	None	eolian loess?
5125+00	4075042.8N	337004.4E	13	Grieta fine sandy loam	ML	0	TR	0	0	0	100	Pale Red	Rapid	Low	Non-Plastic	Hard	NA	None	eolian loess?
5140+00	4075394.0N	336337.7E	13	Grieta fine sandy loam	ML	0	TR	0	0	0	100	Pale Red	Rapid	Low	Non-Plastic	Hard	NA	None	eolian loess?
5220+00	4075962.7N	333724.8E	2 or 13	Grieta fine sandy loam or Barx fine sandy loam	ML	0	TR	0	0	0	100	Pale Red	Rapid	Low	Non-Plastic	Hard	NA	None	eolian loess?
5310+00	4076672.2N	331926.6E	9	Campanile clay	CH	0	TR	0	0	0	100	Red, Brown	Rapid	Low	High	Firm to hard	NA	M	alluvium
5315+00	4076807.9N	331418.9E	2	Barx fine sandy loam	SP	0	10	90	0	0	0	Pale Brown, Red	NA	NA	Non-Plastic	NA	R	None	alluvium

Table 3-7
Lake Powell Pipeline
Field Survey of Soil Characteristics

Station	Northing	Easting	Soil Symbol	Soil Name	USCS Class	% Cobble	% Gravel	% C. Sand	% M. Sand	% F. Sand	% Fines	Color	Fines Dilatancy	Toughness	Plasticity	Fines Consistency	Sand/Gravel Angularity	Cementation	Origin
5315+00	4076628.7N	331393.7E	9	Campanile clay	CL	0	0	0	0	25	75	Pale Brown, Pale Red	Rapid	Low	Low	Firm	R	M	alluvium
5390+00	4077313.1N	329053.2E	14	Grieta loam	ML	0	0	0	0	25	75	Pale Brown, Pale Red	Rapid	Low	Low	Firm to Hard	SR - R	W	alluvium/ eolian
5607+50 HS-2 South	4083914.6N	329129.3E	2	Barx fine sandy loam	SC	0	0	0	0	80	20	Pale Red	Rapid	Low	Low	Firm	R	M	alluvium/ eolian
Hydro System-South Alternative, East Penstock																			
131+00	4097595N	389334E	None	Unknown	CH	0	0	0	0	10	90	Brown	Slow	Low	High	Very Soft	NA	W	alluvium
Hydro System-Southeast Corner Alternative																			
4070+00	4079293.3N	364850.5E	17	Havasupai-Mellenthin Complex	ML, CL	0	0	0	0	0	100	Red	NA	NA	Non-Plastic	NA	NA	NA	partially derived from limestone
ORIGINAL Hurricane Cliffs Forebay and Afterbay and ORIGINAL Sand Hollow Section of LPP Hydro System																			
Hurricane Cliffs Hydro Station	4104781.7N	295166.9E	NNE	Nikey-Ison Complex	GC	10	40	5	5	5	35	Brown, Red	None	Low	Low to Medium	Soft	SA	None	alluvium/ slopewash from ss and limestone
10+00 (N of afterbay)	4106034.1N	294585.8E	NNE	Nikey-Ison Complex	ML	0	0	0	0	0	100	Pale Red, Tan	Rapid	Low	Low	Firm	NA	None	alluvium transported far from source
165+00 Sand Hollow	4107316.4N	291357.6E	HbC	Harrisburg fine sandy loam	ML/GM	0	25	10	5	5	55	Red	None	Low	Low	Soft	SA	None	eolian/ alluvium
210+00 Sand Hollow	4108439.3N	291357.6E	PoD	Pintura Loamy Fine Sand	SP	0	0	0	50	50	0	Red	NA	NA	Non-Plastic	NA	SR - R	None	eolian-derived from Navajo SS
REVISED Hurricane Cliffs Forebay and Afterbay and Sand Hollow Pump Storage Alignment Section of LPP Hydro System																			
42+85 HCHF Penstock at Powerhouse	4104045N	295244E	NNE	Nikey-Ison Complex	SP	5	20	TR	5	60	10	Tan	NA	NA	Non-Plastic	NA	Gravel - A Sand - R	L	alluvial fan outwash / eolian
54+75 HCHF Powerhouse Penstock Tailrace	4104013N	294880E	NNE	Nikey-Ison Complex	SP/SM	2	15	5-8	TR	50	20	Pale Brown	NA	NA	Non-Plastic	NA	Gravel - A Sand - R	L	alluvium / eolian
63+50 Pump Storage Tunnel Alignment	4104579N	292431E	PoD	Pintura Fine Sand	SP	0	0	TR	10	90	TR	Pale Red	NA	NA	Non-Plastic	NA	R	None	alluvium / eolian
90+80 Pump Storage Tunnel Alignment	4105392N	292250E	PoD	Pintura Fine Sand	SP	0	0	TR	5	90	5	Pale Red	NA	NA	Non-Plastic	NA	R	None	alluvium / eolian
116+15 Pump Storage Tunnel Alignment	4106144N	292073E	PoD	Pintura Loamy Fine Sand	SP/SM	0	TR	TR	TR	90	10	Red	NA	NA	Low	NA	R	L	alluvium / eolian
KCWCD Section of LPP Hydro System																			
Kane County	4101627.7N	378477.7E	s8197	Yarts/Palma/ Neville Family - Barx Atchee	SM	0	0	0	0	60	40	Red	NA	NA	NA	NA	R	M	weathered Morrison?



Soil Characteristics Points
Project Pump Station
Project Regulating Tank
Project Hydro Station
Water Conveyance System
Hydro System - South Alignment Alternative

Interstate
US Highway
ST Highway
Hwy
Major Road

Lakes & Reservoirs
Major Rivers & Streams
National Park/Monument
GSENM-Boundary
State Boundaries

FERC Project Number:
12966-001
BLM Serial Numbers:
AZA-34941
UTU-85472

0 0.5 1 2 3 4 Miles

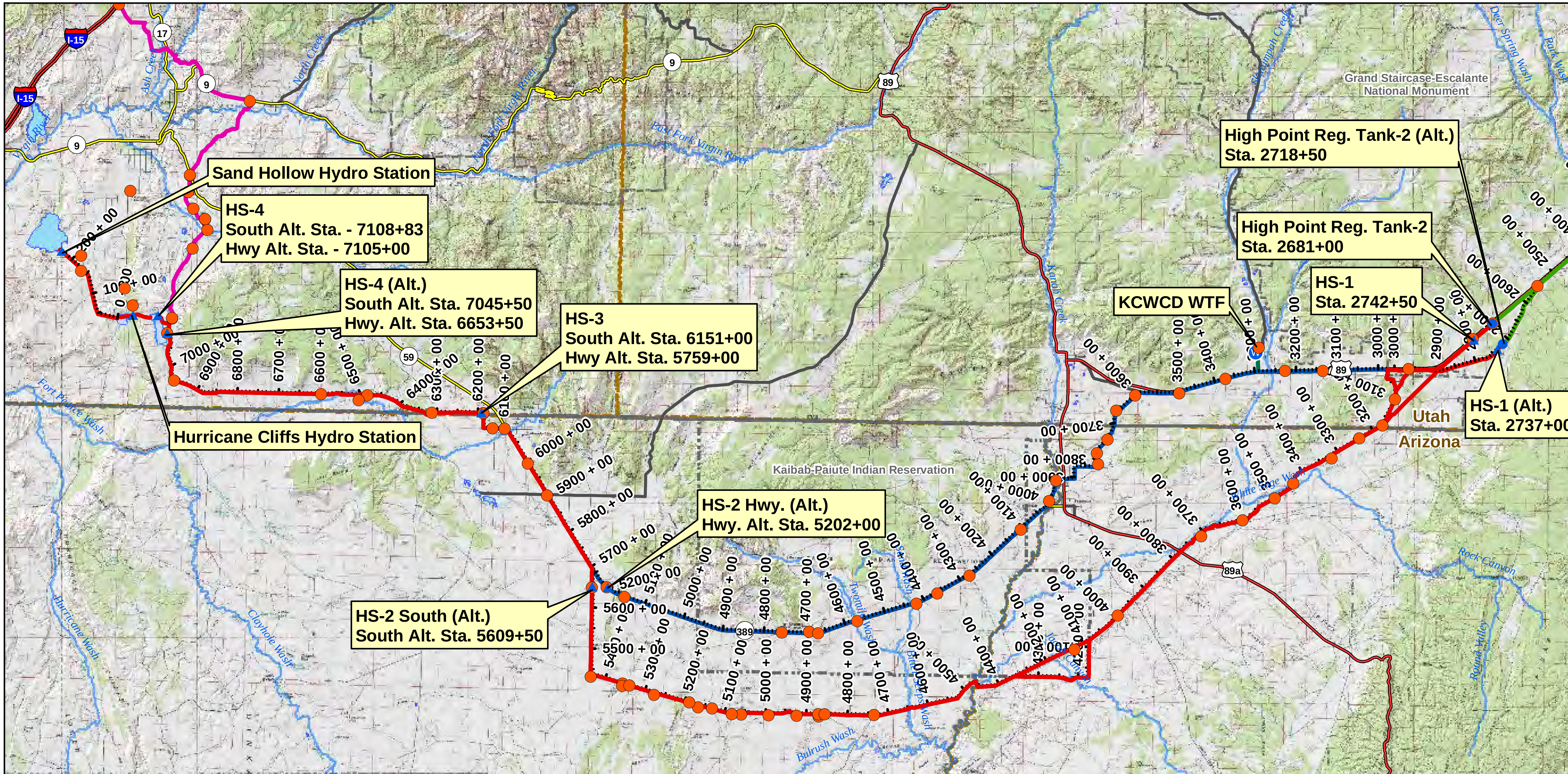
N

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR **Figure 3-5** MWH

Lake Powell Pipeline
Soil Characteristics Points
Water Conveyance System



Soil Characteristics Points	Water Conveyance System	Interstate
Project Pump Station	Hydro System - South Alignment Alternative	US Highway
Project Regulating Tank	Hydro System - Highway Alignment Alternative	ST Highway
Project Hydro Station	Cedar Valley Pipeline System	Hwy
Water Treatment Facility	Hurricane Cliffs Forebay/Afterbay	Major Road
	Lakes & Reservoirs	
	Major Rivers & Streams	

- National Park/Monument
- GSENM Boundary
- Tribal Lands
- State Boundaries
- County Boundaries

FERC Project Number:
12966-001
BLM Serial Numbers:
AZA-34941
UTU-85472

0 1.25 2.5 5 7.5 10 Miles

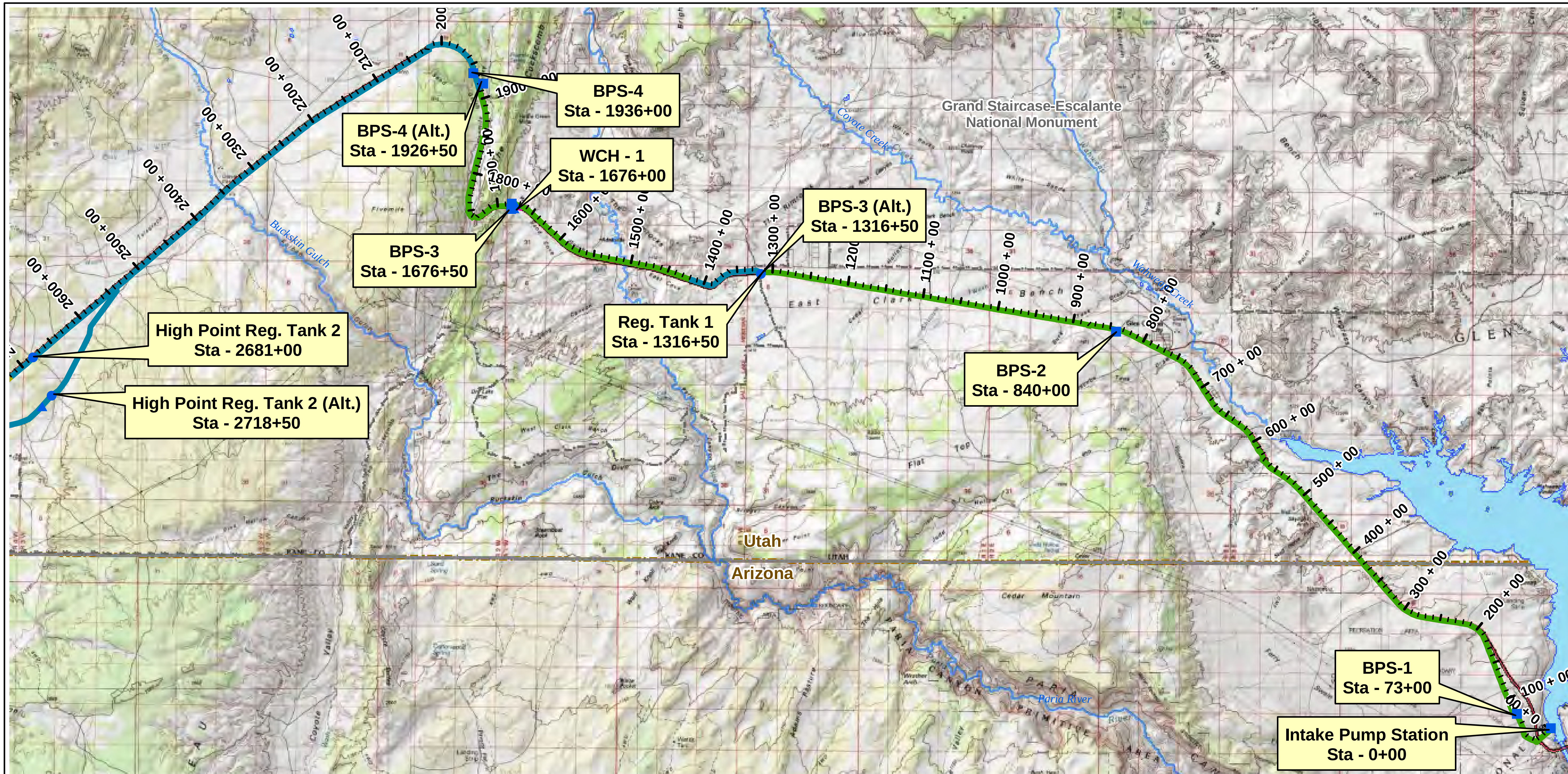
N

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR **Figure 3-6** MWH

Lake Powell Pipeline
Soil Characteristics Points
Hydro System



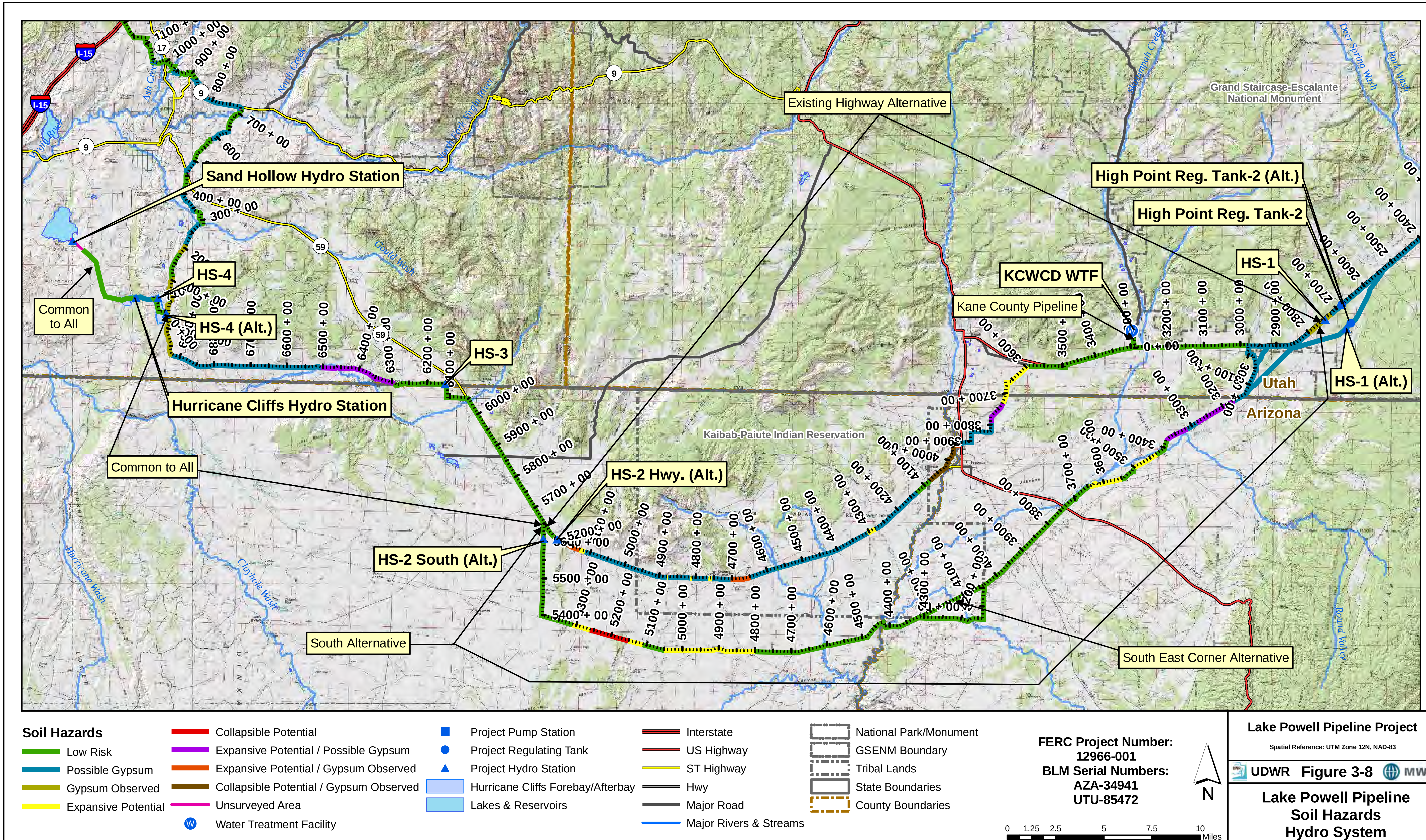
FERC Project Number:
12966-001
BLM Serial Numbers:
AZA-34941
UTU-85472

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR **Figure 3-7** MWH

Lake Powell Pipeline
Soil Hazards
Water Conveyance System


Sand Hollow Hydro Station
Common to All
HS-4
HS-4 (Alt.)
Hurricane Cliffs Hydro Station
Common to All
HS-3
HS-2 Hwy. (Alt.)
HS-2 South (Alt.)
South Alternative
Existing Highway Alternative
Kane County Pipeline
KCWCD WTF
High Point Reg. Tank-2 (Alt.)
High Point Reg. Tank-2
HS-1
HS-1 (Alt.)
South East Corner Alternative
Grand Staircase-Escalante National Monument
Kaibab-Paiute Indian Reservation
Utah
Arizona
Soil Hazards
Low Risk
Possible Gypsum
Gypsum Observed
Expansive Potential
Collapsible Potential
Expansive Potential / Possible Gypsum
Expansive Potential / Gypsum Observed
Collapsible Potential / Gypsum Observed
Unsurveyed Area
Water Treatment Facility
Project Pump Station
Project Regulating Tank
Project Hydro Station
Hurricane Cliffs Forebay/Afterbay
Lakes & Reservoirs
Interstate
US Highway
ST Highway
Hwy
Major Road
Major Rivers & Streams
National Park/Monument
GSENM Boundary
Tribal Lands
State Boundaries
County Boundaries
FERC Project Number:
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AZA-34941
UTU-85472
0 1.25 2.5 5 7.5 10 Miles
N
Lake Powell Pipeline Project
Spatial Reference: UTM Zone 12N, NAD-83
UDWR
Figure 3-8
MWH
Lake Powell Pipeline
Soil Hazards
Hydro System

Table 3-8 Lake Powell Water Conveyance System Soil Hazards		
From Station:	**To Station:**	**Description**
1320+00 WCS	1420+00 WCS	possible gypsum
1910+00 WCS	2680+00 WCS	possible gypsum

Table 3-9 Lake Powell Hydro System Soil Hazards		
From Station:	**To Station:**	**Description**
2680+00 HS	2720+00 HS	possible gypsum
2720+00 HS	2800+00 HS	gypsum observed
2800+00 HS	2980+00 HS	possible gypsum
6295+00 HS	6505+00 HS	expansive potential and possible gypsum
6505+00 HS	6920+00 HS	possible gypsum
6920+00 HS	7045+00 HS	gypsum observed

Table 3-10 Hydro System-Highway Alternative Soil Hazards		
From Station:	**To Station:**	**Description**
3595+00 HWY	3730+00 HWY	expansive potential
3595+00 HWY	3795+00 HWY	expansive potential and possible gypsum
3795+00 HWY	3940+00 HWY	possible gypsum
3940+00HWY	3955+00 HWY	expansive potential and gypsum observed
3955+00 HWY	4070+00 HWY	collapsible and gypsum observed
4130+00 HWY	4270+00 HWY	possible gypsum
4270+00 HWY	4305+00 HWY	expansive potential
4305+00 HWY	4570+00 HWY	possible gypsum
4573+00 HWY	4650+00 HWY	possible gypsum
4650+00 HWY	4705+00 HWY	expansive potential and gypsum observed
4705+00 HWY	4755+00 HWY	possible gypsum
4755+00 HWY	4765+00 HWY	expansive potential
4765+00 HWY	4810+00 HWY	possible gypsum
4810+00 HWY	4815+00 HWY	expansive potential
4815+00 HWY	4875+00 HWY	possible gypsum
4875+00 HWY	4880+00 HWY	expansive potential
4880+00 HWY	5115+00 HWY	possible gypsum
5115+00 HWY	5130+00 HWY	expansive potential
5130+00 HWY	5170+00 HWY	expansive potential and gypsum observed

Table 3-11 Hydro System-South Alternative Soil Hazards		
From Station:	**To Station:**	**Description**
131+00 SOUTH, EAST PENSTOCK	210+00 SOUTH, EAST PENSTOCK	Expansive potential and possible gypsum
2980+00 SOUTH	3165+00 SOUTH	possible gypsum
3165+00 SOUTH	3285+00 SOUTH	expansive potential and possible gypsum
3285+00 SOUTH	3315+00 SOUTH	possible gypsum
3315+00 SOUTH	3380+00 SOUTH	expansive potential and possible gypsum
3430+00 SOUTH	3500+00 SOUTH	expansive potential
3550+00 SOUTH	3645+00 SOUTH	expansive potential
4800+00 SOUTH	5050+00 SOUTH	expansive potential
5110+00 SOUTH	5150+00 SOUTH	expansive potential
5210+00 SOUTH	5260+00 SOUTH	collapsible potential
5260+00 SOUTH	5310+00 SOUTH	expansive potential

3.2.1.5 Geologic Hazards to Human Health and Safety

No geologic hazards to human health and safety were identified in the study area, except for possible risks of slope stability or rockfall that have been addressed previously.

Important Structures and Mineral Resources

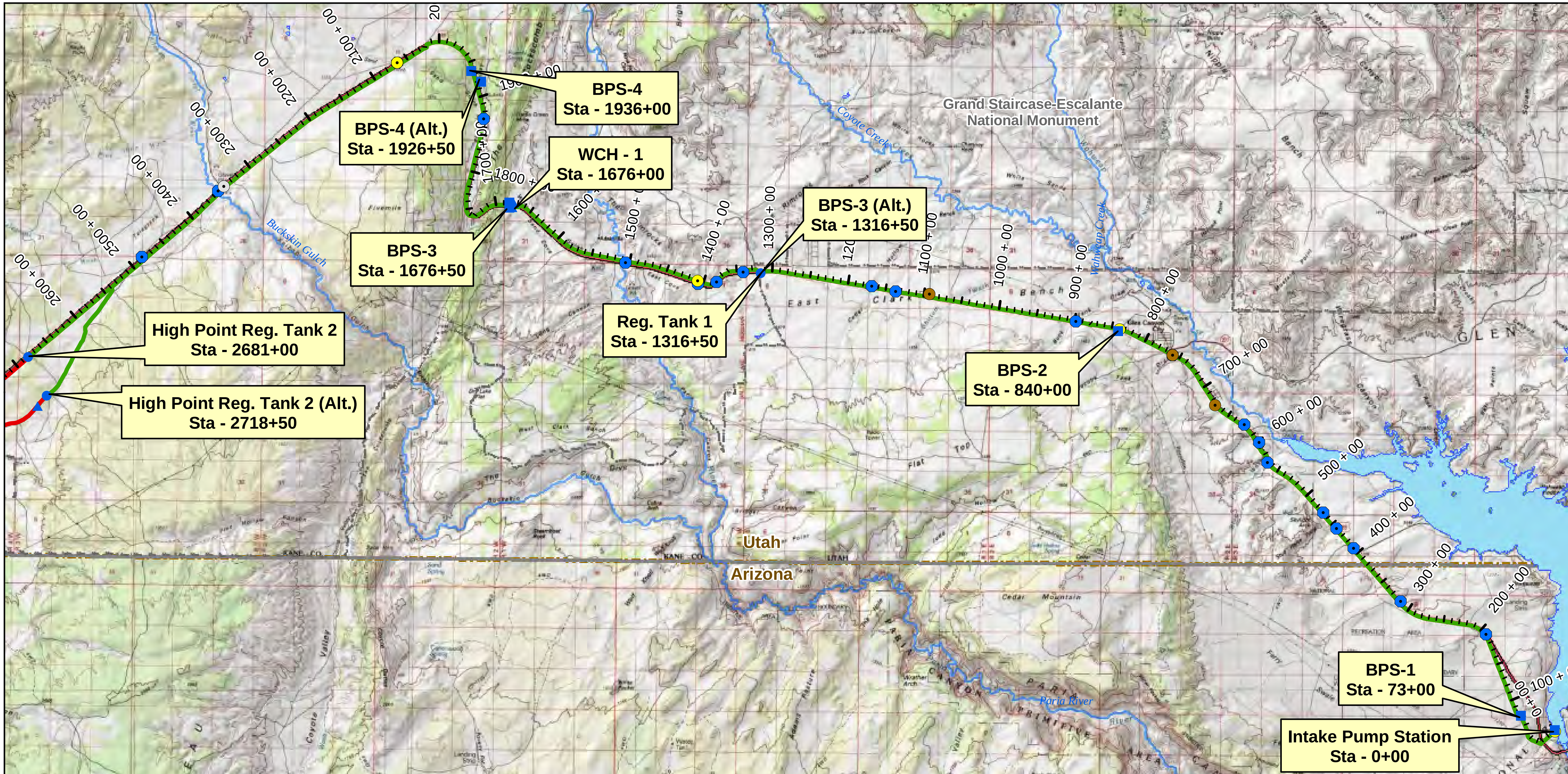
The location coordinates of buildings and other structures encountered during the field survey are summarized in Table 3-12 and shown in Figures 3-9 and 3-10. The structures have been generalized into categories; buildings, quarries, utilities, wells or other.

3.2.1.6 Borrow and Spoil

Locations for borrow material (bedding and backfill) were identified based on U.S. Geological Survey (USGS) topographic maps and aerial photos, visual observations along the alignments, and recommendations from local contractors. Thirty-six potential borrow sites were inspected along the LPP, including pits on both public and private land. Of these, seven were determined to be disturbed sites or rock quarries but not borrow sites. At the remaining 29 sites, the suitability of materials for bedding, potential for significant quantities of borrow material, proximity to pipeline alignments, and accessibility were considered as part of the inspections. Some locations appeared to have potential for both borrow and spoil of excess excavated trench material, or may not be suitable as a borrow source but could provide a convenient and substantial space for spoil of excess trench material. Table 3-13 shows the field inspection results of potential borrow and spoil sites near the LPP alignment alternatives. The locations of these sites are shown on Figures 3-11 and 3-12.

Table 3-12
Lake Powell Pipeline
Field Survey of Physical Characteristics

Station	Northing	Easting	Type	Description
Lake Powell Water Conveyance System				
0+00	4088541.8N	456505.0E	Other	Construction staging area at intake
672+00	4101517.0N	442978.8E	Building	Town of Bigwater
755+00	4103504.2N	441291.0E	Building	BLM Welcome Center building
835+00	4104529.0N	439179.3E	Other	Brass cap survey marker, State Road Right of Way
1092+00	4105941.2N	431625.2E	Building	Town of Churchwells
1415+00	4106462.8N	422409.3E	Other	Brass cap, survey marker
2060+00	4115140.5N	410453.9E	Other	Bench mark, Range R138
2340+00	4110219.3N	403558.5E	Quarry	Gravel quarry
Hydro System-Existing Highway Alternative				
3980+00	4090779.9N	363240.2E	Building	House
4695+00	4080531.5N	345245.7E	Building	Tribal Headquarters Building and gas station
Hydro System- South Alternative				
4100+00	4077951.2N	365894.6E	Other	Survey marker, brass cap
4280+00	4077357.3N	361117.7E	Other	Survey marker, brass cap
5480+00	4079470.7N	329041.0E	Other	Windmill
5580+00	4082673.7N	329104.5E	Well	Two water tanks
Lake Powell Hydro System				
5790+00	4088981.0N	326880.4E	Building	Five houses
6080+00	4095681.7N	321936.8E	Building	2 houses
6270+00	4096825.2N	317303.4E	Other	Windmill
6400+00	4098111.3N	413374.9E	Building	House
6440+00	4098129.9N	312524.9E	Well	Well
6450+00	4097754.2N	311667.3E	Well	Well
6550+00	4098207.8N	309105.2E	Other	Brass cap



Drainages
Building
Other
Quarry
Utility
Well
Project Pump Station
Project Regulating Tank
Project Hydro Station
Water Conveyance System
Hydro System - South Alignment Alternative
Interstate
US Highway
ST Highway
Hwy
Major Road
Lakes & Reservoirs
Major Rivers & Streams
National Park/Monument
GSENM-Boundary
State Boundaries

FERC Project Number:
12966-001
BLM Serial Numbers:
AZA-34941
UTU-85472

0 0.5 1 2 3 4 Miles

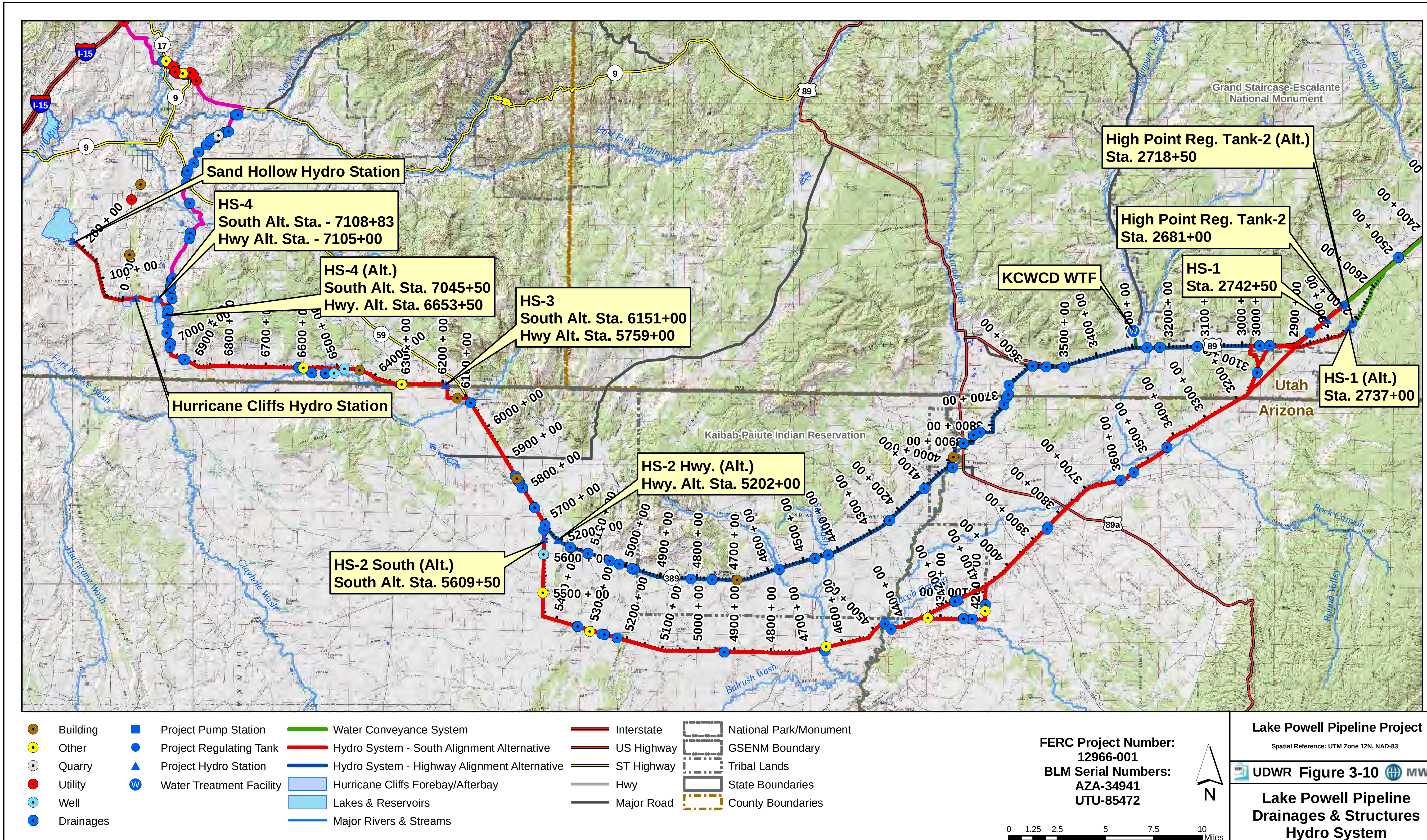
N

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR **Figure 3-9** MWH

Lake Powell Pipeline
Drainages & Structures
Water Conveyance System



Sand Hollow Hydro Station
HS-4
South Alt. Sta. - 7108+83
Hwy Alt. Sta. - 7105+00
HS-4 (Alt.)
South Alt. Sta. 7045+50
Hwy. Alt. Sta. 6653+50
HS-3
South Alt. Sta. 6151+00
Hwy Alt. Sta. 5759+00
Hurricane Cliffs Hydro Station
HS-2 Hwy. (Alt.)
Hwy. Alt. Sta. 5202+00
HS-2 South (Alt.)
South Alt. Sta. 5609+50
KCWCD WTF
High Point Reg. Tank-2 (Alt.)
Sta. 2718+50
High Point Reg. Tank-2
Sta. 2681+00
HS-1
Sta. 2742+50
HS-1 (Alt.)
Sta. 2737+00
Grand Staircase-Escalante
National Monument
Kaibab-Paiute Indian Reservation
Utah
Arizona
Fort Pearce Wash
Hurricane Wash
Clayhole Wash
Bulrush Wash
Kanab Creek
East Fork Virgin River
North Fork Virgin River
North Creek
Johnson Canyon Creek
Deer Spring Wash
Park Wash
Rock Canyon
Round Valley
Building
Other
Quarry
Utility
Well
Drainages
Project Pump Station
Project Regulating Tank
Project Hydro Station
Water Treatment Facility
Water Conveyance System
Hydro System - South Alignment Alternative
Hydro System - Highway Alignment Alternative
Hurricane Cliffs Forebay/Afterbay
Lakes & Reservoirs
Major Rivers & Streams
Interstate
US Highway
ST Highway
Hwy
Major Road
National Park/Monument
GSENM Boundary
Tribal Lands
State Boundaries
County Boundaries
FERC Project Number:
12966-001
BLM Serial Numbers:
AZA-34941
UTU-85472
N
0 1.25 2.5 5 7.5 10 Miles
Lake Powell Pipeline Project
Spatial Reference: UTM Zone 12N, NAD-83
UDWR Figure 3-10 MWH
Lake Powell Pipeline
Drainages & Structures
Hydro System

Table 3-13
Lake Powell Pipeline
Borrow and Spoil Sites

Pit Number	Pit Location	Northing	Easting	Description	Suitable for Pipe Bedding	Potential Spoils Disposal Site	Site Evaluated to be Unsuitable for Project Use (Borrow or Spoil)
P-1	Reclamation Site near LPP Intake at GCNRA	4088541.8N	456505.0E	Large gravel stockpiles on Reclamation land	X		
P-2	AZ DOT Maintenance Yard	4089183.9N	455516.4E	ADOT gravel stockpiles, possible excavation site?	X		
P-3	South of Wahweap Overlook	4090791.2N	455599.7E	Small conglomerate embankment, largely used up		X	
P-4	Northeast Big Water	4104603.2N	441492.7E	Commercial gravel pit, Western Rock Products	X		
P-5	North Big Water	4105452.5N	440619.6E	Commercial gravel pit, Western Rock Products	X		
P-6	Northwest of Big Water	4105156.2N	439791.5E	Small, inactive BLM pit with sand, gravel, and (mostly) fines, largely used up		X	
P-7	Paria River @ HWY-89	4107781.2N	418905.3E	Commercial gravel pit, Western Rock Products	X		
P-8	Buckskin Gulch southwest of HWY 89	4109999.2N	403778.7E	UDOT gravel pit and stockpiles, no authorized access but apparent usable stockpiles	X		
P-9	Buckskin Gulch northeast of Hwy 89	4111144.4N	403209.1E	Large inactive BLM sand/gravel pit with ~50% fines, largely used up	X	X	

Table 3-13
Lake Powell Pipeline
Borrow and Spoil Sites

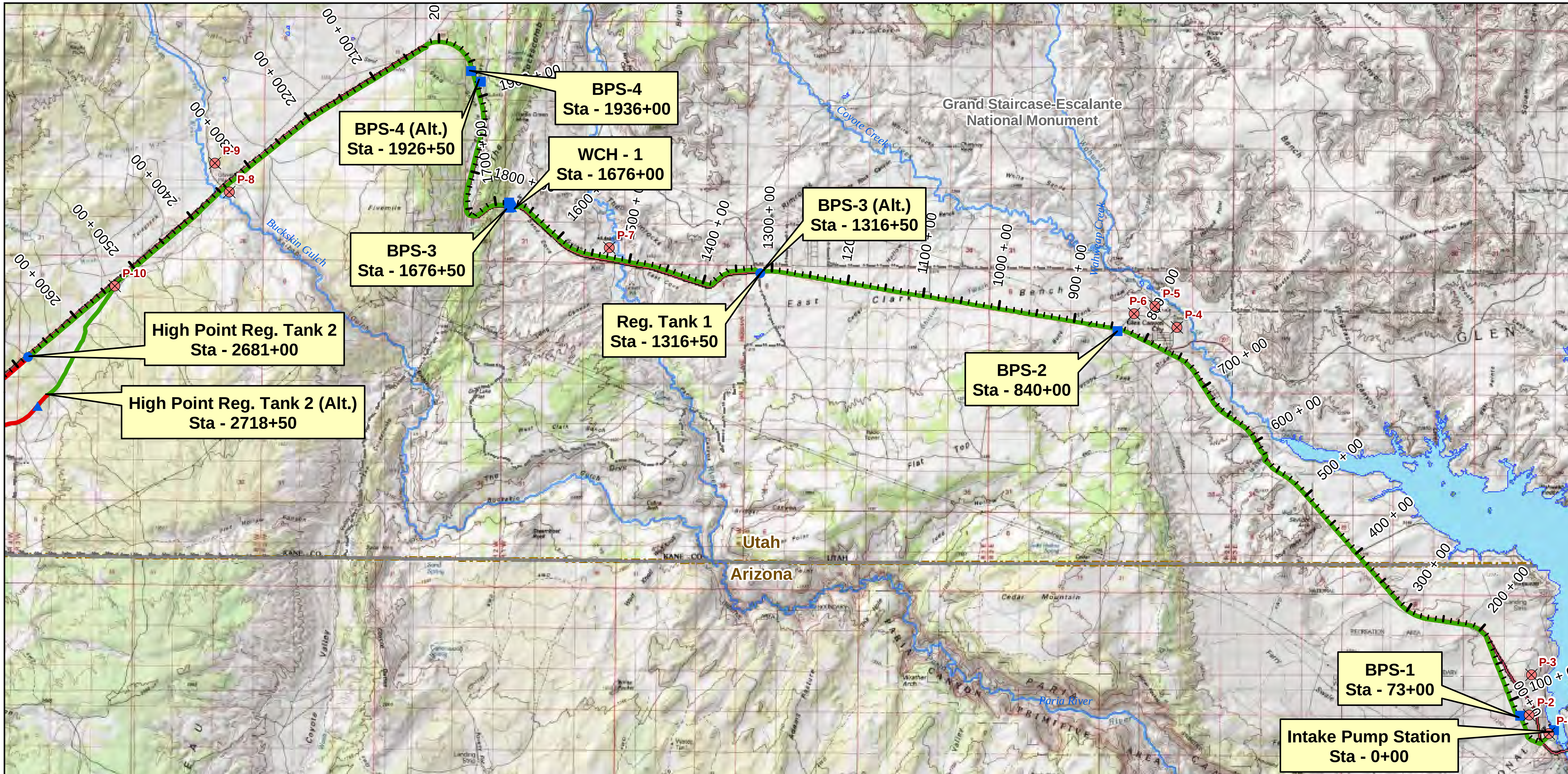
Pit Number	Pit Location	Northing	Easting	Description	Suitable for Pipe Bedding	Potential Spoils Disposal Site	Site Evaluated to be Unsuitable for Project Use (Borrow or Spoil)
P-10	Off of Road K2040 just south of Hwy 89	4106257.4N	399222.5E	~100'x400'x6' sand/gravel pit, ~80% fines, largely used up		X	
P-11	Boundary and south of Hwy 89	4099637.4N	386044.8E	~100'x100'x3' shale pit		X	
P-12	Near Shinarump Rim Road	4098279.0N	385711.1E	BLM sand/gravelly sand pit/embankment derived from TRcp	X		
P-13	Johnson Wash at Shinarump Cliffs	4097929.2N	377893.6E	Access requires crossing private property, permission not granted, not visited			X
P-14	West of Hwy 89-Alt at State Line	4096193.7N	364248.8E	BLM fine sand pit derived from TRcp, adjacent to sand/gravel pit likely derived from TRcs	X	X	
P-15	West of Hwy 89-Alt at State Line	4095717.9N	365200.1E	BLM gravelly sand pit derived from TRcs, some silt, largely used up		X	
P-16	East of Hwy 22, 1.5 miles S. of Hwy 89-Alt	4086557.5N	367031.4E	Clay/shale embankment and pit, very small area			X
P-17	South of Johnson Wash South of Hwy 89-Alt	4085990.8N	370446.1E	Clay/gravelly clay/shale pit, very small area			X
P-18	East of Hwy 22, 3.25 miles South of Hwy 89-Alt	4084104.8N	368707.8E	~200'x200'x8' clay and gravel pit, largely used up, mostly fines		X	

Table 3-13
Lake Powell Pipeline
Borrow and Spoil Sites

Pit Number	Pit Location	Northing	Easting	Description	Suitable for Pipe Bedding	Potential Spoils Disposal Site	Site Evaluated to be Unsuitable for Project Use (Borrow or Spoil)
P-19	West of Hwy 22, 3.25 miles South of Hwy 89-Alt	4083647.6N	367750.5E	Clay and gravel pit, largely used up, mostly fines, small area, difficult access			X
P-20	North of Hwy 89-Alt near AZDOT Milepost 601	4085605.0N	376666.0E	~100'x150'x4' BLM sand/gravel pit/embankment, ~25% gravel, 10% sand, 65% fines, inactive, difficult access			X
P-21	West of Hwy 22, 6.25 miles South of Hwy 89-Alt	4079761.1N	370445.7E	~100'x100'x5' pit with little gravel, mostl fines, largely used up			X
P-22	Just west of Hwy 22, 8.75 miles South of Hwy 89-Alt	4076476.1N	372702.8E	~100'x500'x10 broken siltstone pit, bounded on east side by Hwy 22, mostly weathered soft rock		X	
P-23	West of Hwy 22, 8.75 miles South of Hwy 89-Alt	4075923.6N	371183.5E	~600'x1,000'x25' BLM pit, active, mostly weathered and broken siltstone and limestone, some boulders, processing required			X
P-24	JDM Commercial Pit West of Hwy 22	4070427.7N	369269.0E	Large commercial gravel pit, JDM Sand & Rock	X		

Table 3-13
Lake Powell Pipeline
Borrow and Spoil Sites

Pit Number	Pit Location	Northing	Easting	Description	Suitable for Pipe Bedding	Potential Spoils Disposal Site	Site Evaluated to be Unsuitable for Project Use (Borrow or Spoil)
P-25	South of Hwy 389 at Milepost 26	4083148.6N	356029.4E	Small sand/gravel embankment/pit on private property, probably largely fines, some processing apparent, unable to access			X
P-26	South of Two Mile Wash on Mt Trumbull Rd	4078594.9N	351938.5E	Small embankment shale pit on Kaibab Paiute Indian Reservation, used by Tribe			X
P-27	West of Hwy 389 at Milepost 7	4087022.7N	327642.9E	Very small pit on private land, not authorized to access, probably too small to use			X
P-28	South of Clayhole Rd	4090774.1N	323980.0E	Commercial or municipal gravel facility, Rock Products, availability unclear	X		
P-29	South of Colorado City Municipal Airport	4090960.6N	319988.2E	Airport stockpiles and small pits, does not appear to be a good source			X



- Borrow & Spoil Pit Sites
- Project Pump Station
- Project Regulating Tank
- Project Hydro Station
- Water Conveyance System
- Hydro System - South Alignment Alternative
- Interstate
- US Highway
- ST Highway
- Hwy
- Major Road
- Lakes & Reservoirs
- Major Rivers & Streams
- National Park/Monument
- GSENM-Boundary
- State Boundaries

FERC Project Number:
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BLM Serial Numbers:
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UTU-85472

0 0.5 1 2 3 4 Miles

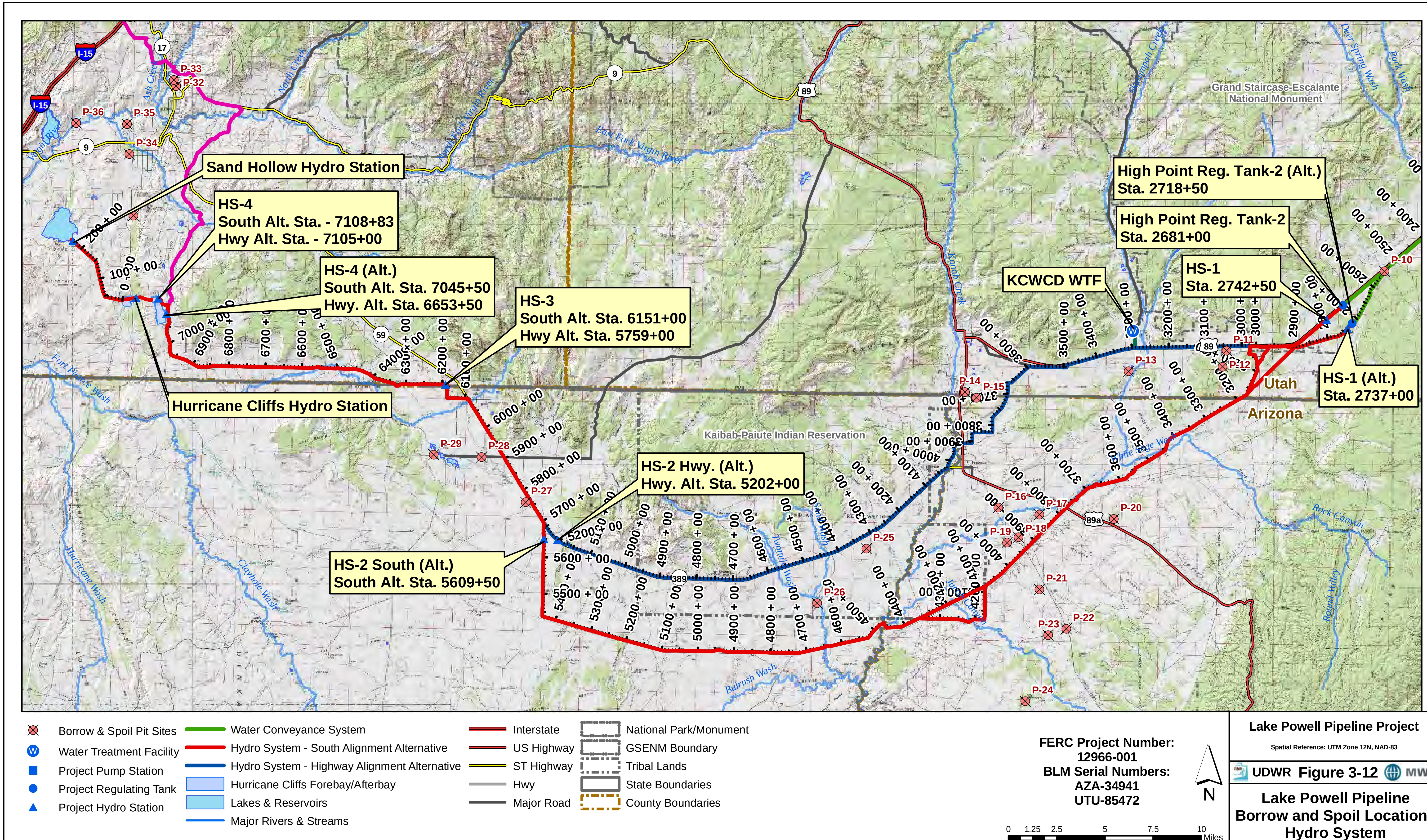
N

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR **Figure 3-11** MWH

Lake Powell Pipeline
Borrow and Spoil Locations
Water Conveyance System


Sand Hollow Hydro Station
HS-4
South Alt. Sta. - 7108+83
Hwy Alt. Sta. - 7105+00
HS-4 (Alt.)
South Alt. Sta. 7045+50
Hwy. Alt. Sta. 6653+50
HS-3
South Alt. Sta. 6151+00
Hwy Alt. Sta. 5759+00
Hurricane Cliffs Hydro Station
HS-2 Hwy. (Alt.)
Hwy. Alt. Sta. 5202+00
HS-2 South (Alt.)
South Alt. Sta. 5609+50
KCWCD WTF
High Point Reg. Tank-2 (Alt.)
Sta. 2718+50
High Point Reg. Tank-2
Sta. 2681+00
HS-1
Sta. 2742+50
HS-1 (Alt.)
Sta. 2737+00
Grand Staircase-Escalante
National Monument
Kaibab-Paiute Indian Reservation
Utah
Arizona
Borrow & Spoil Pit Sites
Water Treatment Facility
Project Pump Station
Project Regulating Tank
Project Hydro Station
Water Conveyance System
Hydro System - South Alignment Alternative
Hydro System - Highway Alignment Alternative
Hurricane Cliffs Forebay/Afterbay
Lakes & Reservoirs
Major Rivers & Streams
Interstate
US Highway
ST Highway
Hwy
Major Road
National Park/Monument
GSENM Boundary
Tribal Lands
State Boundaries
County Boundaries
FERC Project Number:
12966-001
BLM Serial Numbers:
AZA-34941
UTU-85472
0 1.25 2.5 5 7.5 10 Miles
N
Lake Powell Pipeline Project
Spatial Reference: UTM Zone 12N, NAD-83
UDWR Figure 3-12 MWH
Lake Powell Pipeline
Borrow and Spoil Locations
Hydro System

3.2.2 Cedar Valley Pipeline

3.2.2.1 Fault Movement

All of the fault crossings evaluated by FWLA for the CVP section of the pipeline are summarized in Table 3-14. Figures showing the locations of the crossings relative to the pipeline are shown in the FWLA report. The proximity of the Hurricane fault, which lies parallel to most of the CVP alignment and the potentially short recurrence intervals for surface rupture events give the hazards associated with the Hurricane fault a high relevance rating along the entire length of the CVP. The CVP alignment also crosses all of the major traces of the Hurricane Fault. There are several fault crossings that have been evaluated as high relevance in the Segment Boundary (Nephi's Twist) based on the potential for large displacements in these areas. The hazard associated with the faults at the Pintura and Ash Creek graben were determined to be of high significance based on the apparent association of this trace with the Hurricane Fault. There is a housing development downslope of the fault crossings in the Segment Boundary area, increasing the potential for impacts associated with a pipeline rupture. The Pintura and Ash Creek graben fault crossing is not located near a populated area, decreasing the potential impacts associated with a pipeline rupture.

3.2.2.2 Seismic Activity

Review of USGS seismic hazard maps shows that the CVP Alternatives lie within zones of low to moderate potential seismic activity (0.14 to 0.4 gravities Peak Ground Acceleration) with a two-percent probability of exceedance over a 50-year period. However, the CVP Alternative lies parallel to the Hurricane fault system, and several relatively large magnitude earthquakes have occurred along the Hurricane Fault in recorded history, including the 5.8 Richter scale magnitude St. George quake in 1992. Projected PGA is high (>0.41 g) north of the CVP Alternative, north of Cedar City, suggesting some potential for higher PGA near the north end of the alignment.

3.2.2.3 Unstable Slopes

Rocks along the CVP Alternative alignment are primarily volcanic such as basalt and ash flow tuffs over sedimentary rocks. The sedimentary rocks include limestone, sandstone, siltstone, shale, and evaporites. The Moenkopi Formation outcrops along most of the southern half of the CVP. The Virgin Limestone, Timpoweap limestone and sandstone and shale and sandstone from the Middle and Lower Red Members are most prominent.

The rock characteristics observed in the field were compared to existing geologic maps. The rock characteristics observed during the field survey are included in Table 3-15. The locations of survey points are shown on Figure 3-13.

Potential geologic hazards exist along the proposed CVP Alternative alignment. During the field survey, where potential hazard indicators were observed, the area was noted. Upon completing the field survey, the data was extrapolated between survey points using the geologic maps, soil maps and, where available (Washington County, Utah), existing hazard maps. The hazards were separated into 'rock' and 'soil' categories.

Table 3-14
Cedar Valley Pipeline
Fault Intersection Assessment

Map Area	Alignment	Station Range	Rupture Assessment	Urban Development	Preliminary Impact Risk	Remarks
Segment Boundary	CVP	Crossing 1 911 + 45	High significance	Low	Low	Rupture could flood La Verkin Creek
	CVP	Crossing 2 913 + 00	High significance	Low	Low	
	CVP	Crossing 3 919 + 15	High significance	Low	Low	
	CVP	Crossing 4 925 + 85	Moderate - Low significance	Low	Low	
	CVP	Crossing 5 931 + 50	Moderate - Low significance	Low	Low	
	CVP	Crossing 6 935 + 50	Moderate - Low significance	Low	Low	
	CVP	Crossing 7 937 + 60	Moderate - Low significance	Low	Low	
	CVP	Crossing 8 938 + 65	High significance	Low	Low	
	CVP	Crossing 9 941 + 75	High significance	Low	Low	
	CVP	Crossing 10 956 + 00	Moderate - Low significance	Moderate	Low	
	CVP	995 + 00 to 990 + 00	Low significance	Yes	Low	
	CVP	1039 + 40	Not significant	Moderate	Low	
Anderson Junction	CVP	1185+00	Not significant	No	Low	
	CVP	1215+00	Not significant	No	Low	

Table 3-14
Cedar Valley Pipeline
Fault Intersection Assessment

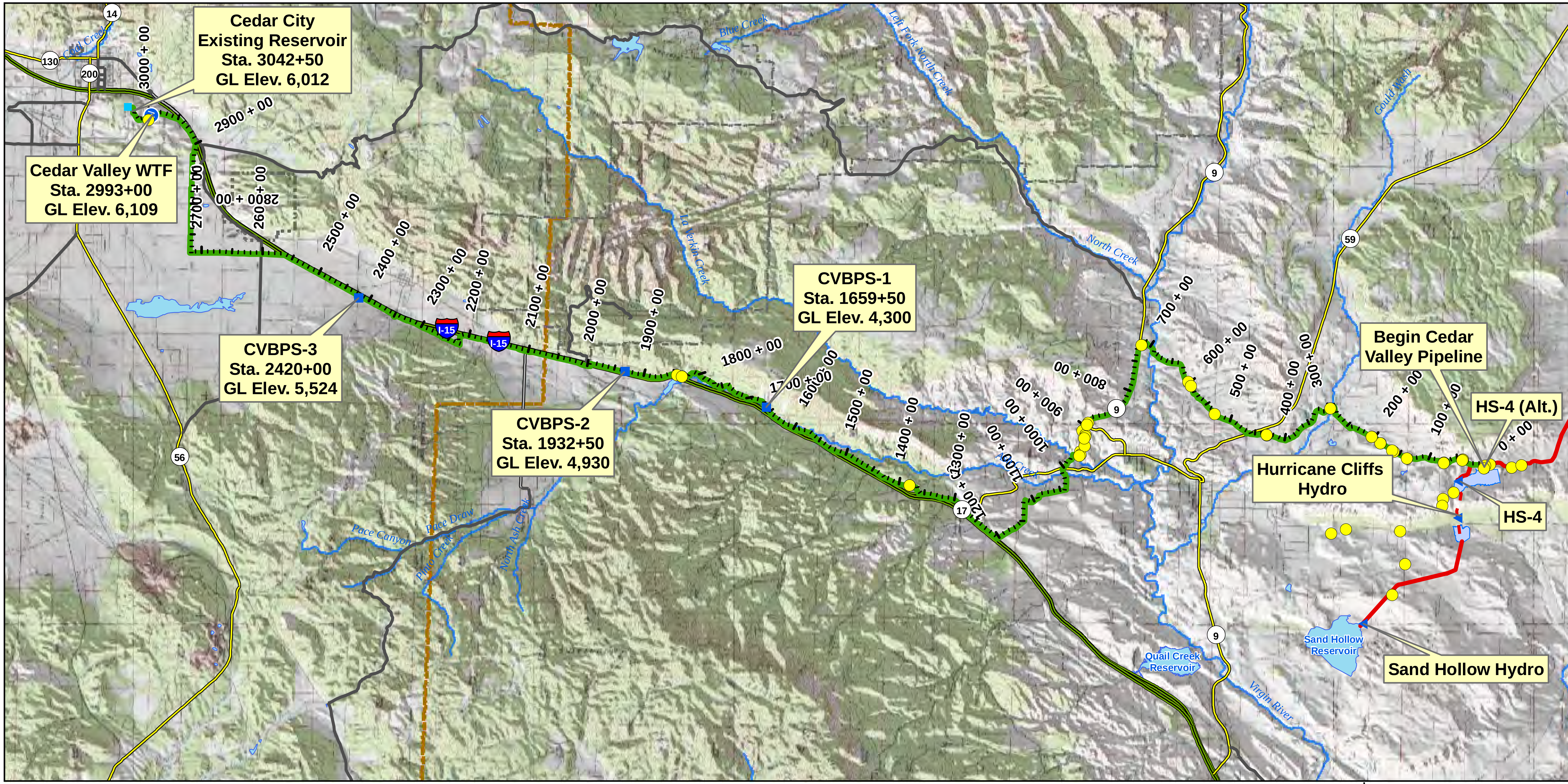
Map Area	Alignment	Station Range	Rupture Assessment	Urban Development	Preliminary Impact Risk	Remarks
Pintura & Ash Creek Graben	CVP	1431 + 40	High significance	No	Low	
Kolob Arch	CVP	1790 + 00 to 1815 + 00	Not significant	No	Low	
Kanarraville area	CVP	2218 + 46	Low significance	No	Low	
	CVP	2230 + 00 to 2370 + 00	Low significance	No	Low	
Cross Hollow Hills	CVP	2785 + 90	Low - Moderate significance	Yes	Low	
	CVP	2872 + 80	Low - Moderate significance	No	Low	
	CVP	2885 + 00	Low - Moderate significance	No	Low	Rupture could flood downslope
	CVP	2899 + 00 and 2903 + 50	Low - Moderate significance	No	Low	
	CVP	2932 + 50	Moderate significance	No	Low	
	CVP	2972 + 00	Not significant	No	Low	
	CVP	2990 + 00	Low significance	No	Low	
	CVP	3027 + 00	Moderate significance	Yes	Low	Rupture could flood downslope

Table 3-15
Cedar Valley Pipeline
Field Survey of Rock Characteristics

Station	Northing	Easting	Symbol	Formation	Lithology	Hardness	Weathering	Alteration	Strength	Color	Texture
0+00	4102720.8N	297700.8E	TRmv	Virgin Limestone member, Moenkopi	limestone	H	S/M	SA	VS/S	tan/gray	FG/MG
40+00	4103789.8N	298125.1E	TRmm	Middle Red Member, Moenkopi	siltstone and interbedded sandstone, some gypsum	S/VS	VS	MA/HA	W/VW	red, brown, gray, white, green	FG
40+00	4103789.8N	298125.1E	Qb	Basalt	basalt boulders	VH/H	VS	SA	ES	black/ rust, blue/ gray	CG
70+00	4104727.1N	297972.3E	TRmv	Virgin Limestone	amorphous to fine grained limestone	H/MH	VS/S	SA	S	white, gray, tan, green	FG
90+00	4106660.2N	292909.5E	Qb	Basalt	basalt flow	VH	S	SA	VS	black, cream	FG
100+00	4107316.4N	291357.6E	Ts	Tuff	thin ash flow tuff	MH	M	SA	MS	tan, cream	CG
140+00	4106577.2N	298192.5E	TRmv	Virgin Limestone	limestone	H/MH	VS/S	SA	S	white, gray, tan, green	FG
160+00	4107314.5N	298579.1E	TRmv	Virgin Limestone	limestone	H/MH	VS/S	SA	S	white, gray, tan, green	FG
165+00	4107240.6N	298534.2E	TRmv	Virgin Limestone	limestone	H/MH	VS/S	SA	S	white, gray, tan, green	FG
190+00	4107895.5N	298955.6E	TRmm/TRmv contact	Middle Red Member, Moenkopi	sandstone/ shale	S/VS	VS	MA/HA	W/VW	red, brown, gray, white, green	FG
190+00	4107895.5N	298955.6E	TRmm/TRmv contact	Virgin Limestone	limestone	H/MH	VS/S	SA	S	white, gray, tan, green	FG
200+00	4108326.8N	299274.2E	TRml	Lower Red Member, Moenkopi	gypsum bed	VS	VS	HA	EW	white	CG
240+50	4019262.1N	299694.0E	TRml	Lower Red Member, Moenkopi	sandstone, siltstone and gypsum	S/VS	VS	CA	W/VW	red, brown, white, green	A
245+00	4110402.7N	300688.7E	Qb	Basalt	fine grained basalt with vessicles	VH/H	VS	SA	ES/VS	dark gray, black	A/FG
295+00	4110402.7N	300688.8E	Qb	Basalt	basalt flow	VH/H	VS	SA	ES	black/ rust, blue/ gray	CG
380+00	4112203.4N	299294.9E	TRml	Lower Red Member, Moenkopi	sandstone, shale	VH/H	MS	SA	VS/S	tan, brown, red	FG/MG/CG
430+00	4113594.4N	299341.2E	TRmt	Timpoweap Member, Moenkopi	fine grained limestone	VH	F/VS	F	ES	tan, yellow, brown	FG
530+00	4116179.2N	300397.6E	TRmt	Timpoweap Member, Moenkopi	limestone	VH	F/VS	F	ES	tan, yellow, brown	FG
590+00	4117384.3N	301818.0E	TRml/TRmt contact	Lower Red Member, Moenkopi	red sandstone	VH/H	MS	SA	VS/S	tan, brown, red	FG/MG/CG
590+00	4117384.3N	301818.0E	TRml/TRmt contact	Timpoweap Member, Moenkopi	limestone	VH	F/VS	F	ES	tan, yellow, brown	FG
590+50	4117513.8N	302024.8E	TRml	Lower Red Member, Moenkopi	sandstone, siltstone and gypsum	S/VS	VS	CA	W/VW	red, brown, white, green	A
680+00	4119061.8N	303319.3E	TRmt	Timpoweap Member, Moenkopi	sandstone, siltstone	S	VS	HA	W/VW	tan, yellow, brown, gray	FG
720+00	4119846.1N	303855.9E	TRmt/Trml contact	Lower Red Member, Moenkopi	fine-grained sandstone	MH	M	SA	S	red	FG
720+00	4119846.5N	303856.7E	TRmt/Trml contact	Timpoweap Member, Moenkopi	limestone	VH	F/VS	F	ES	tan, yellow, brown	FG
890+00	4122517.9N	299965.9E	TRmt	Timpoweap Member, Moenkopi	limestone and weathered shale	H	S/M	SA/MA	VS	tan, gray	FG
910+00	4122800.4N	299570.2E	TRmt/Pkh contact	Timpoweap Member, Moenkopi	limestone	VH	F/VS	F	ES	tan, yellow, brown	FG

Table 3-15
Cedar Valley Pipeline
Field Survey of Rock Characteristics

Station	Northing	Easting	Symbol	Formation	Lithology	Hardness	Weathering	Alteration	Strength	Color	Texture
910+00	4122800.4N	299570.2E	TRmt/Pkh contact	Harrisburg Member, Kaibab	limestone	VH	M	MA	VS	tan, gray	MG
920+00	4122647.7N	299389.7E	TRml	Lower Red Member, Moenkopi	sandstone, shale	VH/H	MS	SA	VS/S	tan, brown, red	FG/MG/CG
952+00	4122917.2N	298530.0E	Qa	Conglomerate	cemented alluvium/ conglomerate over dipping bedrock	NA	NA	NA	NA	NA	NA
958+00	4122883.8N	298381.2E	Qb over Jn	Basalt	basalt	VH/H	VS	SA	ES/VS	dark gray, black	A/FG
958+00	4122883.8N	298381.2E	Qb over Jn	Navajo Sandstone	sandstone	M/S	M/MS	SA	W	pink, tan	MG
960+00	4122948.8N	298318.7E	Jn	Navajo Sandstone	sandstone	M/S	M/MS	SA	W	pink, tan	MG
975+00	4123266.8N	298301.7E	Jn	Navajo Sandstone	sandstone	M/S	M/MS	SA	W	pink, tan	MG
1380+00	4131441.6N	296841.7E	Qbp	Basalt	basalt flow	VH	S	SA	ES	dark gray, black	MG
1380+00	4131441.6N	296841.7E	Tipv	Pine Valley, Igneous Intrusive	coarse grained igneous intrusive	VH	S	SA	ES/VS	gray, tan, black	VCG
1835+00	4142820.8N	302287.9E	Qbpc	Basalt	basalt flow	H	M	MA	S	gray, brown, black, blue	A
1845+00	4143061.2N	302350.8E	Qal/Qb contact	Alluvium	alluvium, boulders, float	NA	NA	NA	NA	NA	NA
1845+00	4143061.2N	302350.8E	Qal/Qb contact	Basalt	basalt	VH/H	VS	SA	ES	black/ rust, blue/ gray	CG
2942+00	4169482.8N	315113.9E	Qb	Basalt	basalt flow	VH	M	MA	ES	brown, gray, blue	FG
2942+00	4169482.8N	315113.9E	Ts	Basin Fill Sedimentary Rocks	tuffaceous sandstone	H	M	SA	S	tan	MG/CG



Rock Characteristics Points
Water Treatment Facility
Project Pump Station
Project Hydro Station
Cedar Valley Pipeline
Hydro System Lake Powell Pipeline
Hurricane Cliffs Pressure Tunnel
Interstate
US Highway
ST Highway
Hwy
Major Road
Hurricane Cliffs Forebay/Afterbay
Lakes & Reservoirs
Major Rivers & Streams
National Park/Monument
County Boundaries
Tribal Lands

FERC Project Number:
12966-001
BLM Serial Numbers:
AZA-34941
UTU-85472

N

0 1.25 2.5 5 7.5 10 Miles

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR **Figure 3-13** MWH

Cedar Valley
Pipeline System
Rock Characteristics Points

The geology and/or rock hazards are shown on Figure 3-14 and include the presence of gypsum in rock, expansive clay bedrock, rockfall, landslides, unstable slopes and steeply dipping bedrock. Areas where geologic hazards were not identified in the field were designated as low risk. However, as-yet unidentified rock hazards may still be present. Rock hazards have been broken up into segments where they are likely to exist along the alignment, and are shown in Table 3-16.

Table 3-16
Cedar Valley Pipeline System Rock Hazards

From Station:	To Station:	Description
0+00 CVP	5+00 CVP	rockfall hazard
130+00 CVP	180+00 CVP	rockfall hazard
180+00 CVP	245+00 CVP	rockfall hazard
315+00 CVP	330+00 CVP	rockfall hazard
690+00 CVP	700+00 CVP	rockfall hazard
910+00 CVP	975+00 CVP	rockfall hazard
1005+00 CVP	1015+00 CVP	rockfall hazard
1370+00 CVP	1395+00 CVP	rockfall hazard
1555+00 CVP	1850+00 CVP	rockfall hazard
2990+00 CVP	3040+00 CVP	rockfall hazard and slope stability

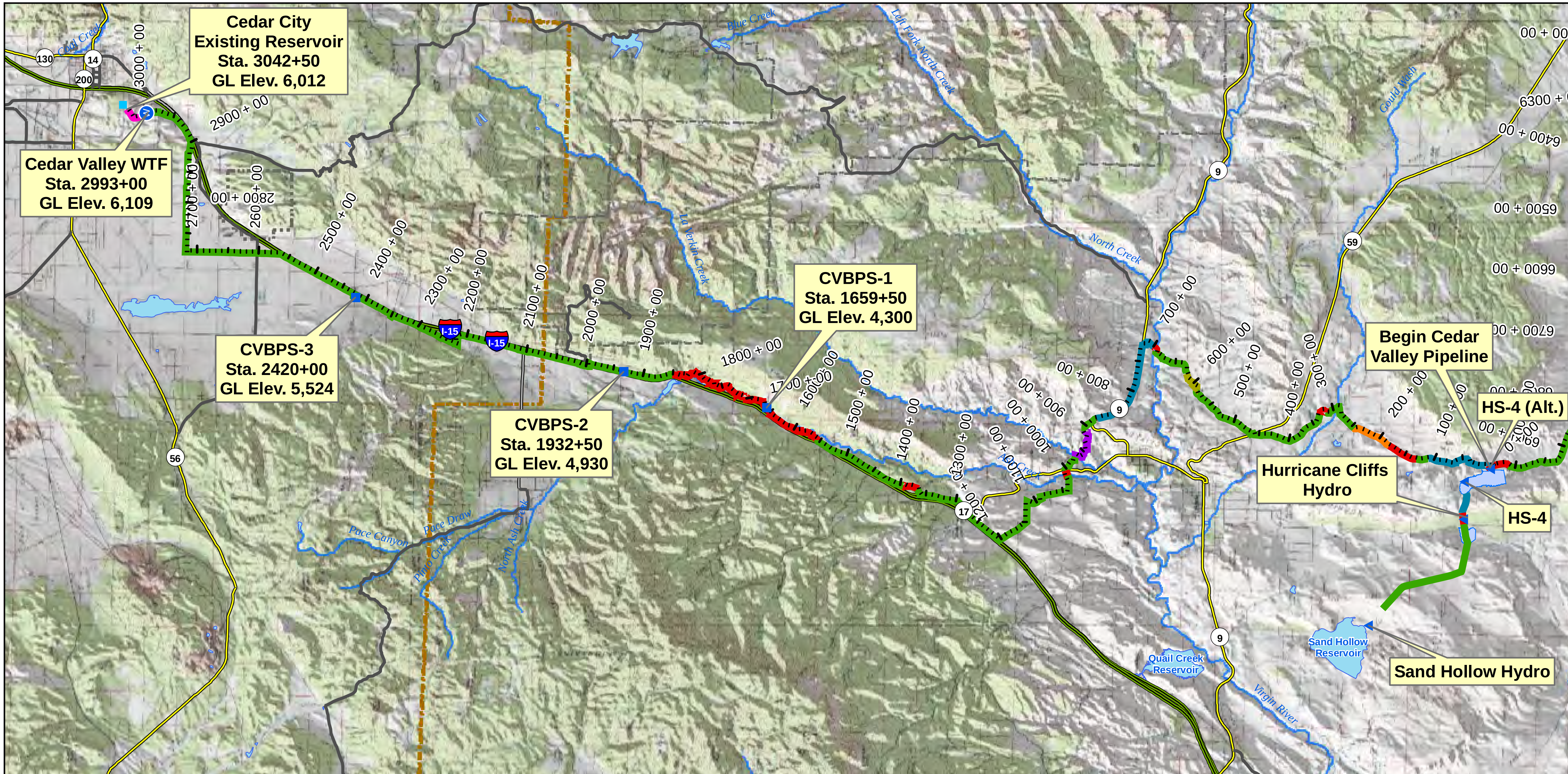
3.2.2.4 Expansive, Collapsible Soils and Subsidence

Soils along the CVP Alternative alignment are typically composed of alluvial, eolian and fluvial deposits and terraces. Some soils are weathered-in-place residual soil over shallow sedimentary bedrock. This is especially common over outcrops of Middle and Lower Red Moenkopi formations. Large alluvial fans cover most of the northern half of the alignment. These soils are typically fine grained silt with some sand but there are several areas where cobbles and large boulders are prevalent.

The soil characteristics observed in the field were compared to the NRCS descriptions. The soil characteristics observed during the field survey are provided in Table 3-17. The locations of the field survey points are shown on Figure 3-15.

Potential geologic hazards exist along the proposed CVP Alternative alignment. During the field survey, where potential hazard indicators were observed, the area was noted. Upon completing the field survey, the data was extrapolated between survey points using the geologic maps, soil maps and, where available (Washington County, Utah), existing hazard maps. The hazards were separated into ‘rock’ and ‘soil’ categories.

Soil hazards are shown on Figure 3-16 and include the presence of gypsiferous soils and soil with expansive or collapsible potential. Areas where geologic hazards were not identified were designated as low risk. However, as-yet unidentified soil hazards may still be present. Soil hazards have been broken up into segments where they are likely to exist along the alignment, and are shown in Table 3-18 below.



Water Treatment Facility
Project Pump Station
Project Hydro Station

Rock Hazards

- Low Risk
- Possible Gypsum
- Gypsum Observed
- Expansive Potential
- Rockfall Hazard
- Rockfall Hazard / Possible Gypsum
- Rockfall Hazard / Gypsum Observed
- Rockfall Hazard / Slope Stability
- Rockfall Hazard / Steeply Dipping Bedrock

- Interstate
- US Highway
- ST Highway
- Hwy
- Major Road
- Hurricane Cliffs Forebay/Afterbay
- Lakes & Reservoirs
- Major Rivers & Streams
- National Park/Monument
- County Boundaries
- Tribal Lands

FERC Project Number:
12966-001
BLM Serial Numbers:
AZA-34941
UTU-85472

0 1.25 2.5 5 7.5 10 Miles

N

Lake Powell Pipeline Project

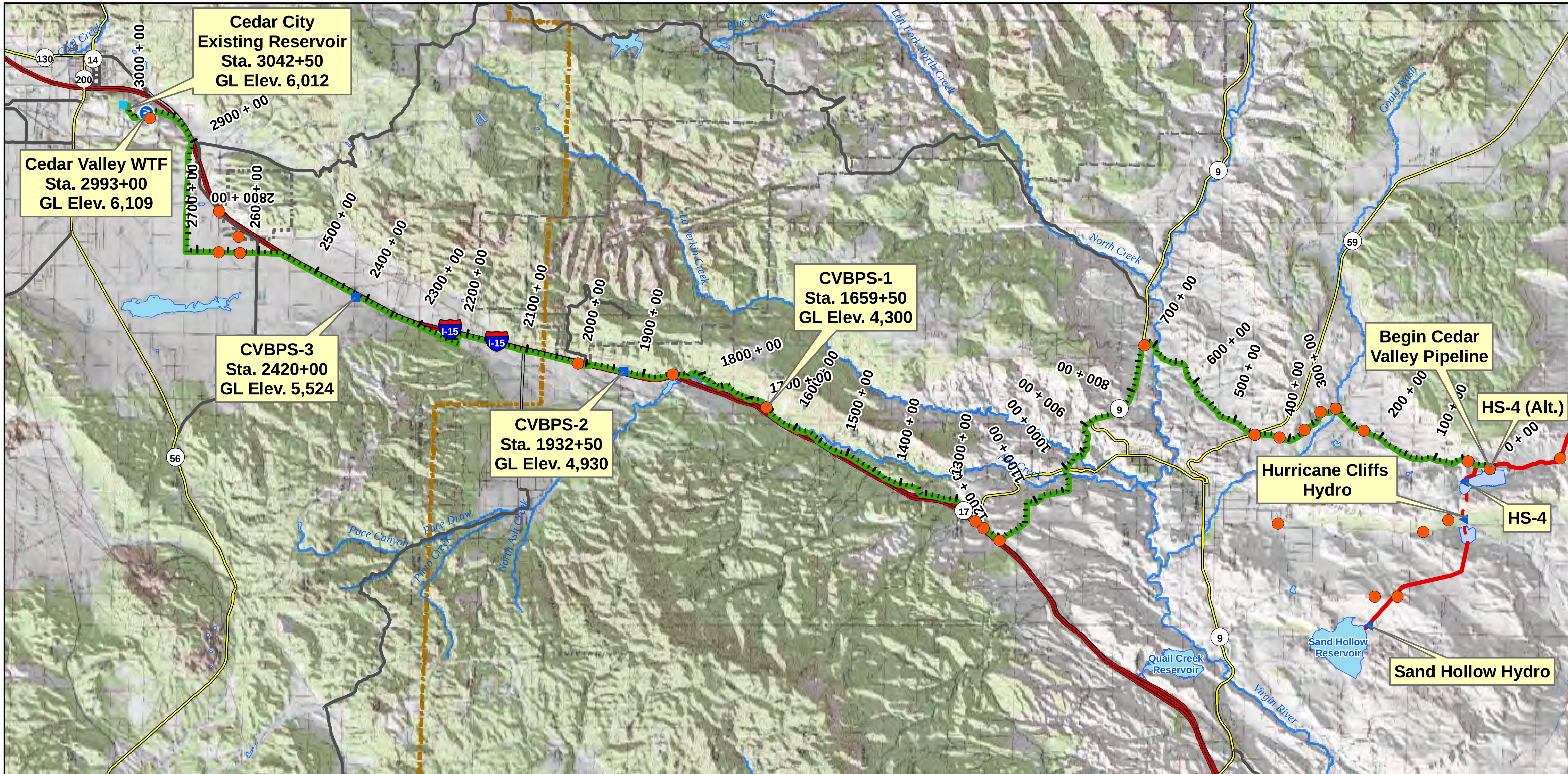
Spatial Reference: UTM Zone 12N, NAD-83

UDWR **Figure 3-14** MWH

Cedar Valley Pipeline System Rock Hazards

Table 3-17
Cedar Valley Pipeline
Field Survey of Soil Characteristics

Station	Northing	Easting	Soil Symbol	Soil Name	USCS Class	% Cobble	% Gravel	% C. Sand	% M. Sand	% F. Sand	% Fines	Color	Fines Dilatancy	Toughness	Plasticity	Fines Consistency	Sand/Gravel Angularity	Cementation	Origin
0+00	4102733.0N	297708.1E	EA	Eroded Land-Shalet Complex	CL-CH	10	TR	0	0	10	80	Tan, Pale Brown	Slow	Low	Medium	Firm	NA	W	residual Virgin Limestone
40+00	4103804.6N	298090.3E	BB	Badland	ML	5	TR	5	10	10	70	Red, Brown	Slow	Low	Low	Soft	NA	W	weathered Moenkopi
230+00	4108978.8N	299597.7E	SH	Schmutz Loam	ML	5	TR	0	0	10	85	Pale Brown	Rapid	Low	Low	Soft	SR	W	old alluvium
295+00	4110366.2N	300691.9E	PED	Pastura-Esplin Complex	SP	5-10	5	<5	<5	70	10	Red, Brown	NA	NA	Non-Plastic	Hard	SR	W	alluvium from basalt
320+00	4111132.7N	300527.4E	GA	Gullied Land	CL	TR	5	0	0	0	95	Red	Slow to Rapid	Low	Medium	Hard	SR - SA	M	alluvium
350+00	4111133.0N	300527.5E	GA	Gullied Land	CL	TR	5	0	0	0	95	Red	Slow to Rapid	Low	Medium	Hard	SR - SA	Moderate	Alluvial
365+00	4111917.9N	299644.0E	EA	Eroded Land-Shalet Complex	ML	10	5	0	0	15	70	Tan, Brown	Rapid	Low	Low	Very Soft	SR	W	alluvium or weathered in place TRml
410+00	4113164.0N	299258.9E	EA	Eroded Land-Shalet Complex	ML	10	5	0	0	15	70	Tan, Brown	Rapid	Low	Low	Very Soft	SR	W	alluvium or weathered in place TRml
455+00	4114383.3N	299400.8E	YZE	Yaki-Zukan Complex	SM	0	TR	TR	TR	70	30	Tan	Rapid	Medium	Low	Soft	SR	W	alluvium from TRms
720+00	4119851.6N	303835.4E	MFD	Mespun Fine Sand	SP	0	5	0	0	95	0	Pale Red	NA	NA	Non-Plastic	NA	R	W	weathered in place or alluvium from ss
1205+00	4127046.4N	294156.4E	MFD	Mespun Fine Sand	SP	0	5	0	0	95	0	Pale Red	NA	NA	Non-Plastic	NA	R	W	weathered in place or alluvium from ss
1230+50	4127836.5N	294771.6E	VHD	Veyo-Curhollow Complex	SP	25	10	0	0	60	5	Pale Brown	NA	NA	Non-Plastic	NA	SR	W	alluvial fan
1250+00	4128236.6N	295100.8E	VHD	Veyo-Curhollow Complex	SP	25	10	0	0	60	5	Pale Brown	NA	NA	Non-Plastic	NA	SR	W	alluvial fan
1660+00 (CBPS-1)	4138603.1N	300756.9E	CHF	Collbran very cobbly clay loam	SC	0	5	0	0	75	20	Tan	NA	NA	Medium	Hard	SA	W	alluvium
1850+00	4143236.6N	302385.0E	MEG	Menfee-Rock outcrop Complex	SC/CL	5	10	5	5	25	50	Brown, Red	Rapid	Medium	Medium	Soft	SA - SR	W	alluvium
2015+00	4147953.3N	302936.0E	NaC	Naplene Silt loam	CH	0	<5	0	0	0	95	Red	Rapid	Low	High	Firm	NA	W	alluvium from Moenkopi
2630+00	4164703.1N	308418.6E	455	Quichipa silty clay loam	CH/MH	0	0	0	0	0	100	Brown	Rapid	Low	High	Soft	NA	W	alluvium
2640+00	4164780.7N	309216.0E	NaC	Naplene Silt loam	CH	0	<5	0	0	0	95	Red	Rapid	Low	High	Firm	NA	W	alluvium from Moenkopi
2665+00	4165766.7N	308451.5E	307	Ashdown clay loam	CH/MH	0	0	0	0	0	100	Brown	Slow	Low	High	Soft to Firm	NA	W	alluvium
2715+00	4165739.4N	310488.6E	NaC	Naplene Silt loam	CH	0	<5	0	0	0	95	Red	Rapid	Low	High	Firm	NA	W	alluvium from Moenkopi
2942+00 (CVP WTP)	4169182.8N	315113.9E	364	Denmark Gravelly Loam	CH	5	10	5	0	0	70	Pale Brown	Rapid	Low	Med. To High	Hard	SA - SR	W	alluvium



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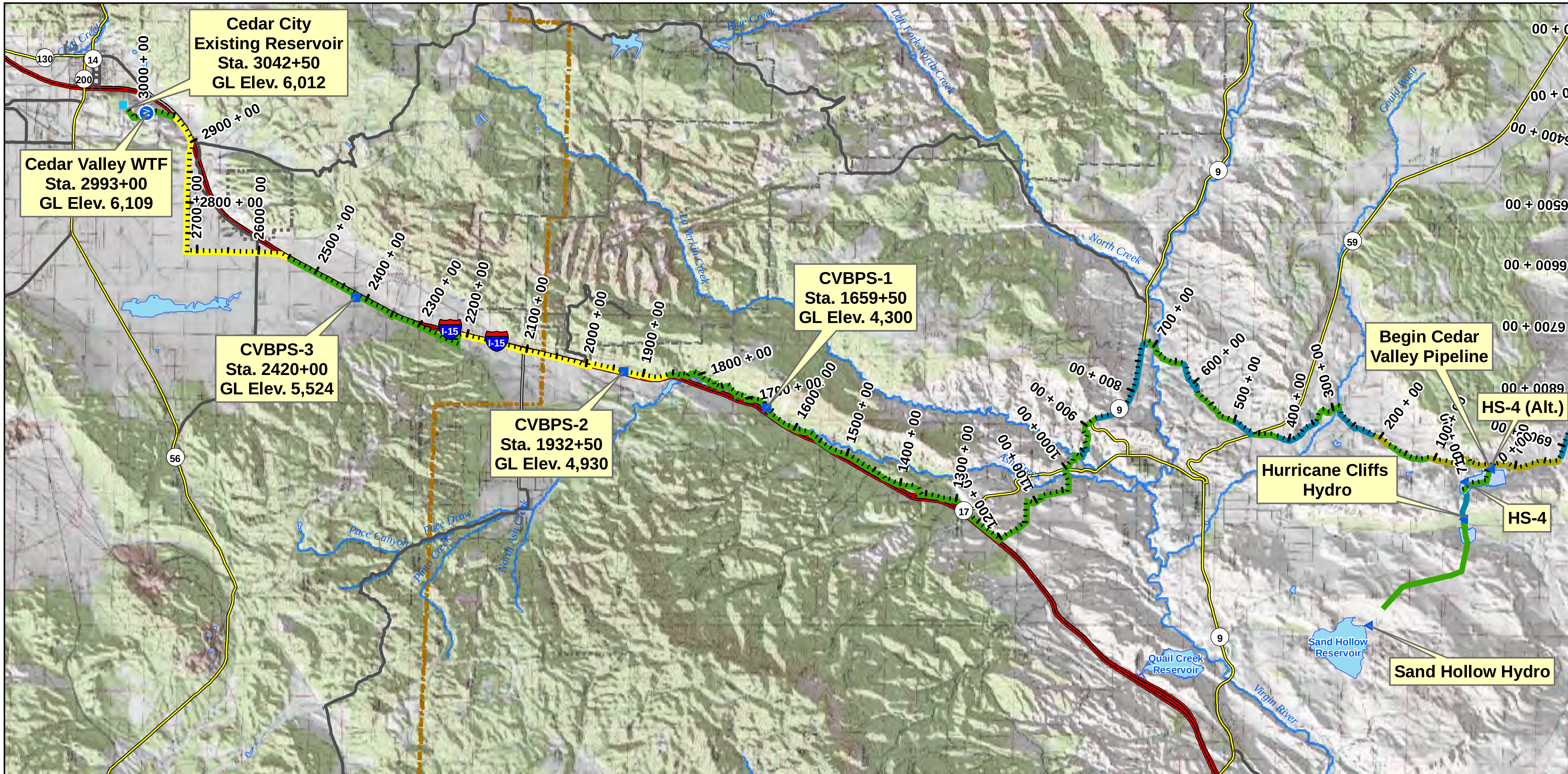
Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR **Figure 3-15** MWH

Cedar Valley Pipeline System Soil Characteristics Points



Water Treatment Facility
Project Pump Station
Project Hydro Station

Soil Hazards

Low Risk
Possible Gypsum
Gypsum Observed
Expansive Potential
Collapsible Potential
Expansive Potential / Possible Gypsum
Expansive Potential / Gypsum Observed
Collapsible Potential / Gypsum Observed

Interstate
US Highway
ST Highway
Hwy
Major Road
Hurricane Cliffs Forebay/Afterbay
Lakes & Reservoirs
Major Rivers & Streams
National Park/Monument
County Boundaries
Tribal Lands

FERC Project Number:
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0 1.25 2.5 5 7.5 10 Miles

N

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR **Figure 3-16** MWH

Cedar Valley Pipeline System Soil Hazards

Table 3-18 Cedar Valley Pipeline System Soil Hazards		
From Station:	**To Station:**	**Description**
00+00 CVP	35+00 CVP	gypsum
40+00 CVP	110+00 CVP	gypsum
180+00 CVP	210+00 CVP	gypsum
210+00 CVP	285+00 CVP	possible gypsum
340+00 CVP	420+00 CVP	possible gypsum
460+00 CVP	500+00 CVP	possible gypsum
580+00 CVP	640+00 CVP	possible gypsum
715+00 CVP	880+00 CVP	possible gypsum
940+00 CVP	960+00 CVP	possible gypsum
1860+00 CVP	2210+00 CVP	expansive potential
2550+00 CVP	2950+00 CVP	expansive potential

In addition to these hazards, land subsidence associated with overpumping of groundwater is occurring in the Cedar Valley (UGS 2009). Subsidence has resulted in soil fissures in two areas: west and northwest of Quichipa Lake, and north of the City of Enoch. Land has subsided in these areas from a few inches to a few feet, causing damage to roads and reversing flow in some gravity drainage pipes. Sinkholes associated with the soil fissures have been observed to allow water to flow directly into the ground, possibly providing a direct, unfiltered conduit for surface water to flow into the aquifer.

3.2.2.5 Geologic Hazards to Human Health and Safety

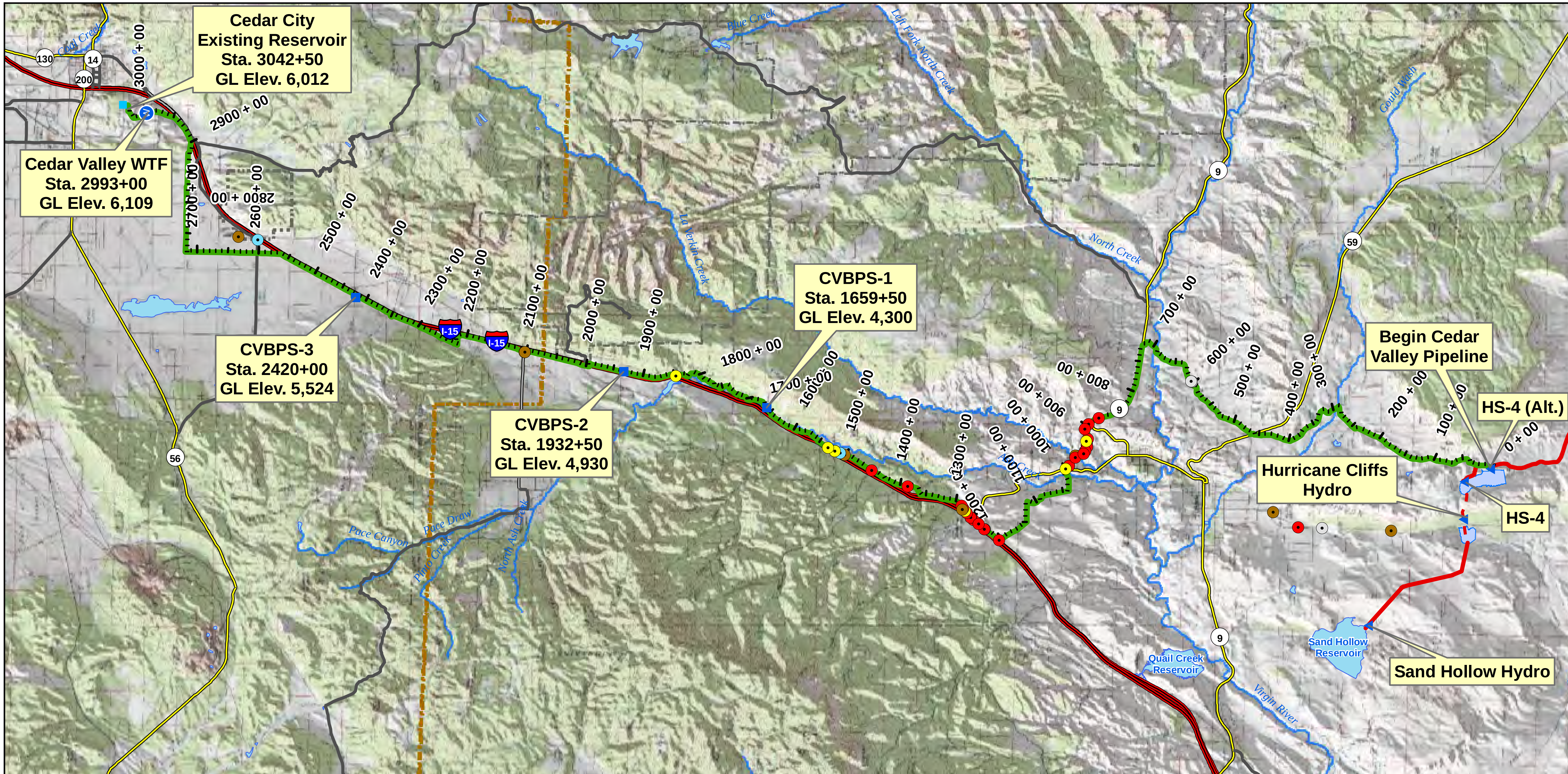
No geologic hazards to human health and safety were identified in the study area, except for potentially unstable slopes or rockfall hazards that have been addressed previously.

3.2.2.6 Important Structures and Mineral Resources

The location coordinates of buildings and other structures encountered during the field survey are summarized in Table 3-19 and shown in Figure 3-17. The structures have been generalized into categories; buildings, quarries, utilities, wells or other.

Table 3-19
Cedar Valley Pipeline
Field Survey of Physical Features

Station	Northing	Easting	Type	Description
590+50	4117513.8N	302024.8E	Quarry	Stone Quarry
610+00	4117549.9N	302046.7E	Quarry	Quarry stock area
875+00	4122119.1N	300227.9E	Utility	Pipeline airvalve
895+00	4122618.0N	299924.5E	Utility	Manhole
905+00	4122814.1N	299676.1E	Utility	Manhole
935+00	4122715.9N	298949.0E	Utility	Manhole
935+00	4122737.5N	299072.0E	Other	Survey marker
940+00	4122714.9N	298881.2E	Utility	Manhole
945+00	4122707.9N	298798.9E	Utility	Manhole
950+00	4122786.3N	298592.1E	Utility	Manhole
970+00	4122873.5N	298456.0E	Utility	Manhole
995+00	4123272.3N	298370.3E	Building	15 ft by 15 ft Building
995+00	4123598.2N	297860.7E	Building	House and other outbuildings
1000+00	4123282.2N	298274.7E	Utility	Water and irrigation lines
1005+00	4123762.1N	297705.1E	Other	Highway 17
1205+00	4127062.5N	294165.3E	Utility	Manhole
1230+00	4127774.9N	294723.3E	Building	15 ft by 15 ft Building
1230+00	4127792.4N	294713.2E	Utility	Waterline
1240+00	4128081.0N	294973.7E	Utility	waterline
1250+00	4128339.1N	295180.6E	Utility	Fire hydrant
1280+00	4128465.3N	295289.2E	Utility	Fire hydrant
1280+00	4128479.8N	295300.9E	Utility	Gas Pipeline running under hwy 15
1280+00	4128663.0N	295516.9E	Utility	Fire hydrant
1280+00	4128765.7N	295609.4E	Other	Road Crossing
1280+00	4128842.1N	295756.3E	Utility	Fire hydrant
1280+00	4128930.4N	295889.0E	Utility	Fire hydrant
1280+00	4128879.5N	295700.8E	Building	Building
1385+00	4131590.2N	296845.4E	Utility	Manhole
1400+00	4133388.3N	297625.9E	Utility	Manhole
1505+00	4134712.7N	298409.2E	Building	House and other outbuildings
1510+00	4134950.5N	298486.7E	Well	Well
1845+00	4143103.4N	302323.5E	Other	Gate
2100+00	4150585.4N	334871.9E	Building	Texaco Gas Station
2600+00	4163837.1N	309066.9E	Well	Well
2630+00	4164781.4N	309214.7E	Building	Houses



Building	Water Treatment Facility	Interstate	Hurricane Cliffs Forebay/Afterbay
Other	Project Pump Station	US Highway	Lakes & Reservoirs
Quarry	Project Hydro Station	ST Highway	Major Rivers & Streams
Utility	Cedar Valley Pipeline	Hwy	National Park/Monument
Well	Hydro System Lake Powell Pipeline	Major Road	County Boundaries
	Hurricane Cliffs Pressure Tunnel		Tribal Lands

FERC Project Number:
12966-001
BLM Serial Numbers:
AZA-34941
UTU-85472

N

0 1.25 2.5 5 7.5 10 Miles

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR **Figure 3-17** MWH

Cedar Valley Pipeline System Drainages & Structures

3.2.2.7 Borrow and Spoil

Locations for borrow material (bedding and backfill) were identified based on U.S. Geological Survey (USGS) topographic maps and aerial photos, visual observations along the alignments, and recommendations from local contractors. Sixteen potential borrow sites were inspected near the CVP, including both public and private borrow sites. Of these, three were determined to be disturbed sites or stone quarries but not borrow sites. At the remaining 13 sites, the suitability of materials for bedding, potential for significant quantities of borrow material, proximity to pipeline alignments, and accessibility were estimated as part of the inspections. Some locations appeared to have potential for both borrow and spoil of excess trench excavated material, or may not be suitable as a borrow source but could provide a convenient and substantial space for spoil of excess trench material. Table 3-20 shows the results of inspection of potential borrow and spoil sites near the Cedar Valley Pipeline System. The locations of these sites are shown on Figure 3-18.

Table 3-20
Cedar Valley Pipeline
Evaluation of Potential Borrow and Spoil Sites

Pit No.	Pit Location	Northing	Easting	Description	Suitable for Pipe Bedding	Potential Spoils Disposal Site	Site Evaluated to be Unsuitable for Project Use (Borrow or Spoil)
P-30	Cinder Cone at base of Little Creek Mtn.	4109678.6N	304808.3E	Large collection of cinder pits, cinders of various sizes, probably too soft to use			X
P-31	Hurricane Cliffs Pit South of Dick Stout Air Field	4110899.9N	294972.1E	Large commercial gravel pit, Hurricane Ready-Mix	X		
P-32	Just east of La Verkin	4121693.3N	298544.1E	Large commercial gravel pit, Interstate Rock Products	X		
P-33	Just east of La Verkin	4122179.2N	298341.6E	Large commercial gravel pit, Interstate Rock Products	X		
P-34	Southwest Hurricane	4116007.9N	294633.0E	Commercial gravel pit, Strattons	X		
P-35	Cinder Cone northwest of Hurricane	4118520.6N	294427.5E	Cinder pits, materials probably too soft to use			X
P-36	Pit next to Virgin River north of Hurricane West Substation	4118601.0N	290188.7E	Large commercial pit, ownership unknown	X		

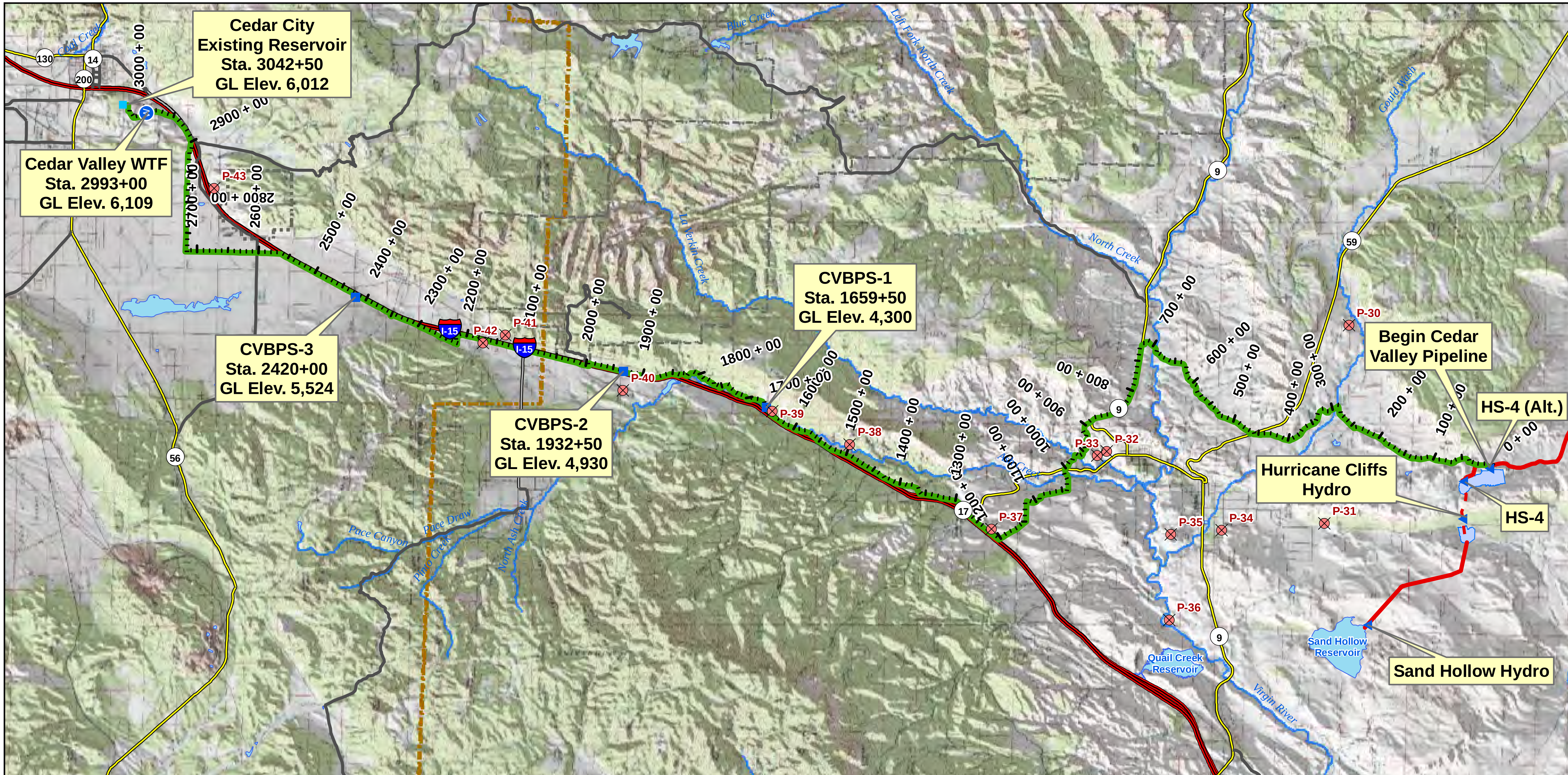
Table 3-20
Cedar Valley Pipeline
Evaluation of Potential Borrow and Spoil Sites

Pit No.	Pit Location	Northing	Easting	Description	Suitable for Pipe Bedding	Potential Spoils Disposal Site	Site Evaluated to be Unsuitable for Project Use (Borrow or Spoil)
P-37	Pit near Anderson Junction, near I-15 MP 26	4127430.6N	294688.9E	~200'x300'x6' BLM sand pit, fine silty sand derived from Jk or Jn	X	X	
P-38	Pit East of Milepost 32 on I-15 near Pintura on Ash Creek	4134452.7N	298899.8E	Large commercial or possibly UTD pit, ownership not determined, not authorized to access	X		
P-39	Pit at CBPS-1 on Ash Creek	4138305.5N	300550.5E	Large commercial pit, Snowfield Rock Products	X		
P-40	Pit west of Kolob Ranch Development	4145705.9N	301573.5E	Small private pit, cobbly silty sand			X
P-41	Pit west of mile post 43 on I-15	4151532.8N	304324.5E	Small embankment cut on state school trust land, little gravel in silty matrix, mostly massive rock and boulders remaining, largely used up			X

Table 3-20
Cedar Valley Pipeline
Evaluation of Potential Borrow and Spoil Sites

Pit No.	Pit Location	Northing	Easting	Description	Suitable for Pipe Bedding	Potential Spoils Disposal Site	Site Evaluated to be Unsuitable for Project Use (Borrow or Spoil)
P-42	Pit northeast of Milepost 43 on I-15	4152652.3N	303933.0E	Commercial landscape rock pit, mostly cobble			X
P-43	East Side I-15 at Milepost 53	4165982.4N	311607.1E	Small private pit, unable to access; soils on adjacent land mostly gravelly silt			X

UTM NAD 83 Zone 12



Borrow & Spoil Pit Sites
Water Treatment Facility
Project Pump Station
Project Hydro Station
Cedar Valley Pipeline
Hydro System Lake Powell Pipeline
Hurricane Cliffs Pressure Tunnel
Interstate
US Highway
ST Highway
Hwy
Major Road
Hurricane Cliffs Forebay/Afterbay
Lakes & Reservoirs
Major Rivers & Streams
National Park/Monument
County Boundaries
Tribal Lands

FERC Project Number:
12966-001
BLM Serial Numbers:
AZA-34941
UTU-85472

0 1.25 2.5 5 7.5 10 Miles

N

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR **Figure 3-18** MWH

Cedar Valley Pipeline System Borrow and Spoil Locations

Chapter 4
Environmental Consequences (Impacts)

4.1 Significance Criteria

The following criteria were used in this evaluation to determine whether impacts associated with the LPP, CVP, and appurtenances would be significant. Significance criteria were established based on the impact topics identified herein, which were identified in the Study Plan. Impacts are considered significant only if they would occur within the design life of the Project (75 years), and could not be mitigated by design.

4.1.1 Fault Movement

Fault movement impacts would be considered significant if the rate of displacement would result in pipeline rupture. The minimum total allowable displacement that would result in pipeline rupture has not been determined, but for large diameter steel pipe the displacement tolerance is likely to be at least 75 mm (about three inches). Thus, an average displacement rate of 1 mm/yr or more would be more likely to result in pipeline rupture during the design life of the Project and therefore could cause a significant impact.

4.1.2 Seismic Activity

Seismic activity would have a significant impact if an earthquake would create unstable foundation conditions for the pipeline or associated features, resulting in pipeline deformation or rupture, or pipeline feature failure. This instability could include liquefaction of underlying soils or slope failure above or below the pipeline or associated features. Proper seismic design would prevent substantial damage to the pipeline or associated features in the event of an earthquake under most circumstances. A risk of a significant impact would be high if all or part of an alignment alternative is located in a zone with high (greater than about 0.4 gravity) Peak Ground Acceleration (PGA) with a two percent or greater probability of exceedance within 50 years, and this would occur in a location with a high probability of liquefaction (saturated, sandy soil within the pipeline trench depth or excavated depth of pipeline facilities; for practical purposes a depth of 15 feet was assumed for the LPP and 10 feet for the CVP).

4.1.3 Unstable Slopes

Slope failure along the pipeline alignments would be considered a significant impact if the slope failure were caused by construction or operation of the pipeline or associated features, and if the slope failure resulted in injury to humans, damage of major human structures, or damage to the environment (significant and long-term erosion; discharges to streams, rivers, lakes or reservoirs causing degradation of water quality as defined by Utah or Arizona state law; or long-term loss of important wildlife habitat).

4.1.4 Expandable, Collapsible, or Subsiding Soils or Rocks

Geologic hazards from soil or rock conditions would have a significant impact if such conditions would occur and would cause deformation or failure of foundation conditions underlying the pipeline or associated features sufficient to cause pipeline rupture or failure of associated pipeline features.

4.1.5 Geologic Hazards to Human Health and Safety

Impacts associated with geologic hazards to human health or safety associated with construction or operation of the pipeline and associated features would be considered significant if the impacts of geologic hazards resulted in human injury or death, or presented a serious risk to human health.

4.1.6 Important Structures and Mineral Resources

Construction or operation impacts on important human structures would be significant if they would result in major damage to the structures. Major damage includes damage requiring replacement, or repairs that would cost more than 25 percent of the value of the structure, or damage which renders the structure inoperable or unusable.

4.1.7 Borrow and Spoil

Impacts associated with borrow of material for pipeline or structure bedding would be significant if extraction of the borrow material causes new and substantial disturbance of land from the extraction source areas.

Impacts associated with disposal (spoil) of excess excavated material would be significant if disposal of spoils would cause substantial changes in runoff patterns, turbid runoff that would discharge to rivers, streams, or lakes, or create unstable slope conditions.

4.2 Potential Impacts Eliminated From Further Analysis

No impacts were eliminated from further analysis.

4.3 South Alternative Impacts

4.3.1 Construction Impacts

4.3.1.1 Fault Movement

The rate of fault movement on faults crossed by the South Alternative alignment and associated hydraulic conveyance and hydropower segments of the LPP are believed to be no more than 0.2 mm/yr on average for the Paunsaugunt Fault and less than that for the Sevier Fault. The displacement rate for other faults crossed by the South Alternative alignment is unknown but this is probably because the remaining faults appear to be less active. The duration of construction activities is too short to be affected by such low rates of displacement. Therefore no impacts would occur during construction.

4.3.1.2 Seismic Activity

Major earthquakes can occur associated with faults along the South Alternative alignment and are likely to occur during the design life of the Project; however, most measured earthquakes in the vicinity have been associated with the Basin and Range Province or the transition zone between the Colorado Plateau and the Basin and Range, both of which are west of the South Alternative alignment. This probably would diminish the potential impacts of earthquake activity on the South Alternative alignment. Proper bedding and pipeline design and construction would further minimize seismic effects. The alignment lies within a zone of low to moderate projected PGA with a two-percent probability of exceedance over a 50-year period. Therefore no impacts would occur.

4.3.1.3 Unstable Slopes

Locations where rockfall and steep slopes exist along the various alignments, including the South Alternative and associated alignment sections, are shown in Tables 3-3, 3-5, and 3-6. Nine locations were identified that are subject to rockfall hazards on steep slopes. These locations are primarily associated with channel crossings or adjacent loose rock outcrops on steep slopes. These locations may be subject to failure, particularly in the event of an earthquake. Individual locations would need to be examined before heavy earthwork, especially blasting, could take place, and site stabilization measures or removal of rock and soil at risk of failure may need to occur before proceeding. If these precautions are followed, no significant impacts would occur.

4.3.1.4 Expandable, Collapsible, or Subsiding Soils or Rocks

Substantial sections of the South Alternative may be subject to expandable, collapsible, or subsiding soils or rocks, as identified in Tables 3-8, 3-9, 3-11, and 3-12. These are primarily associated with gypsiferous soils, which are susceptible to subsidence if gypsum is extensively wetted because gypsum can dissolve, leaving voids. Expansive soils occur in some places along the alignment and are associated with clay deposits, primarily montmorillonite derived from basalts. Construction in such materials may require special design considerations, such as over-excavation and placement of additional bedding, may be necessary. If design considerations are implemented where appropriate, no significant impacts would occur.

4.3.1.5 Geologic Hazards to Human Health and Safety

Geologic hazards to human health and safety would be minimized by following appropriate and site-specific precautions, including trench shoring or sloping, slope stabilization where applicable, and other standard construction safety practices. Therefore no significant impacts would occur.

4.3.1.6 Important Structures and Mineral Resources

Human structures within 1,000 feet of the South Alternative are shown in Table 3-12. The primary risk of damage is associated with the effects of blasting during trenching, since none of the structures are in the direct alignment (excluding highway crossings, which are not included as part of this evaluation and in any event will be repaired as necessary). Structures or groups of structures that may be at risk from blasting include the Town of Big Water, Utah and a windmill at Station 6270+00; all other important structures are not near trench sections that would require blasting. Special blasting methods may need to be employed to minimize the transfer of energy through rock and soil to the structures. At Big Water, most of the town overlies several feet of soil. This would help to absorb and therefore help minimize the transfer of energy to the buildings. Use of lower-energy blasting methods at closer spacings would minimize the effects of blasting near structures. Therefore no significant impacts would occur.

4.3.1.7 Borrow and Spoil

It is anticipated that most, if not all, material for the pipe zone and underlying bedding will be obtained from commercial sand and gravel pits. Some public pits have been identified and may be used, but these are not likely to be major sources of material. All borrow will be obtained from existing disturbed sites, either public or private. Therefore no significant impacts associated with obtaining borrow materials would occur.

Disposal of spoils is expected to be primarily, if not entirely, by spreading within the alignment right of way. This spreading will be in accordance with practices that would be reviewed and approved by the governing public agencies, including BLM, NPS, UDOT and ADOT as well as on private lands. In most locations, less than one foot of spoils is anticipated to be spread across the alignment right of way. Where spreading is not allowed or is not sufficient to dispose of all spoils, materials will be deposited in existing, largely used-up gravel pits. All spoiled materials would be reclaimed by stabilization practices and seeding with an approved seed mix. Therefore no significant impacts associated with spoils would occur.

4.3.2 Operation and Maintenance Impacts

4.3.2.1 Fault Movement

The Paunsaugunt Fault has a projected displacement rate of <0.2 mm/yr, and the Sevier Fault displacement rate is 0.04 to 0.18 mm/yr. The displacement rates for the other faults crossed by the South Alternative alignment are not known, but these faults appear to be less active, which is why displacement rates have not been determined. A displacement of 0.2 mm/yr, which exceeds average displacement rates for the most active faults (including the Paunsaugunt and Sevier faults) would result in a total displacement of 15 mm over the Project design life. Therefore no significant impacts associated with fault movement would occur.

4.3.2.2 Seismic Activity

Major earthquakes can occur associated with faults along the South Alternative alignment and are likely to occur during the design life of the Project; however, most measured earthquakes in the vicinity have been associated with the Basin and Range Province or the transition zone between the Colorado Plateau and the Basin and Range, both of which are west of the South Alternative alignment. This probably would diminish the potential impacts of earthquake activity on the South Alternative alignment. Proper bedding and pipeline design and construction would further minimize seismic effects. The alignment lies within a zone of low to moderate projected PGA with a two-percent probability of exceedance over a 50-year period. Therefore no impacts would occur.

Saturated sandy soils may be encountered at the crossing of the Paria River. However, the projected PGA is low, and proper design and construction would minimize the risks of impacts associated with liquefaction at this location. Therefore no significant impacts would occur associated with liquefaction.

4.3.2.3 Unstable Slopes

Locations where rockfall and steep slopes exist along the various alignments, including the South Alternative and associated alignment sections, are shown in Tables 3-3 through 3-6. These locations may be subject to failure, particularly in the event of an earthquake, but because the pipeline will be buried this probably would not affect the pipeline operations or maintenance, and conversely the operation and maintenance of the pipeline is unlikely to affect the slope stability. Therefore no significant impacts would occur.

4.3.2.4 Expandable, Collapsible, or Subsiding Soils or Rocks

Substantial sections of the South Alternative alignment may be subject to expandable, collapsible, or subsiding soils or rocks, as identified in Tables 3-8, 3-9, 3-11 and 3-12. These are primarily associated with gypsiferous soils, which are susceptible to subsidence if gypsum is extensively wetted because gypsum can dissolve, leaving voids. Expansive soils occur in some places along the alignment and are associated with clay deposits, primarily montmorillonite derived from basalts. If design considerations are implemented where appropriate, no significant impacts would occur associated with operations and maintenance.

4.3.2.5 Geologic Hazards to Human Health and Safety

Geologic hazards to human health and safety during operations and maintenance would be minimized if appropriate design and construction practices are followed. Therefore no significant impacts would occur.

4.3.2.6 Important Structures and Mineral Resources

No significant impacts would occur in connection with operations and maintenance.

4.3.2.7 Borrow and Spoil

No significant impacts would occur associated with operations and maintenance.

4.4 Existing Highway Alternative Impacts

4.4.1 Construction Impacts

4.4.1.1 Fault Movement

The rate of fault movement on faults crossed by the Existing Highway Alternative alignment and associated hydraulic conveyance and hydropower segments of the LPP are believed to be no more than 0.2 mm/yr on average. The duration of construction activities is too short to be affected by such low rates of displacement. Therefore no impacts would occur during construction.

4.4.1.2 Seismic Activity

Impacts associated with seismic activity for the Existing Highway Alternative would be similar to impacts for the South Alternative. No significant impacts would occur.

4.4.1.3 Unstable Slopes

Locations where rockfall and steep slopes exist along the Existing Highway Alternative alignment and associated alignment sections, are shown in Table 3-3, 3-4, and 3-6. Five locations were identified that are subject to rockfall hazards on steep slopes. These locations are primarily associated with channel crossings or adjacent loose rock outcrops on steep slopes. The slope failure hazards are similar to the hazards for the South Alternative; therefore no impact would occur if appropriate precautions are taken.

4.4.1.4 Expandable, Collapsible, or Subsiding Soils or Rocks

Impacts associated with expandable, collapsible, or subsiding soils or rocks for the Existing Highway Alternative alignment would be similar to impacts for the South Alternative alignment and are a result of gypsiferous soils, expansive clays, or gypsiferous or clay-mineral rocks, as identified in Table 3-8, 3-9, 3-10, and 3-11. If design considerations are implemented where appropriate, no significant impacts would occur.

4.4.1.5 Geologic Hazards to Human Health and Safety

Geologic hazards to human health and safety would be minimized by following appropriate and site-specific precautions, including trench shoring or sloping, slope stabilization where applicable, and other standard construction safety practices. This would be the same as for the South Alternative. Therefore no significant impacts would occur.

4.4.1.6 Important Structures and Mineral Resources

Human structures within 1,000 feet of the Existing Highway Alternative alignment are shown in Table 3-12. The primary risk of damage is the same as for the South Alternative and includes the same structures, which are located on sections that are common to both alternatives. Therefore no significant impacts would occur if appropriate precautions are taken.

4.4.1.7 Borrow and Spoil

Impacts associated with borrow and spoils for the Existing Highway Alternative would be the same as for the South Alternative. Therefore no significant impacts would occur.

4.4.2 Operation and Maintenance Impacts

4.4.2.1 Fault Movement

Impacts associated with fault movement for the Existing Highway Alternative alignment would be similar to the South Alternative. Therefore no significant impacts associated with fault movement would occur.

4.4.2.2 Seismic Activity

Impacts associated with seismic activity for the Existing Highway Alternative alignment would be the same as for the South Alternative. Proper bedding and pipeline design and construction would further minimize seismic effects. Therefore no impacts would occur.

4.4.2.3 Unstable Slopes

Impacts associated with slope failure during operation and maintenance for the Existing Highway Alternative are the same as for the South Alternative. No significant impacts would occur.

4.4.2.4 Expandable, Collapsible, or Subsiding Soils or Rocks

Substantial sections of the Existing Highway Alternative alignment may be subject to expandable, collapsible, or subsiding soils or rocks, as identified in Table 3-8, 3-9, 3-10, and 3-11. These are primarily associated with gypsiferous soils, which are susceptible to subsidence if gypsum is extensively wetted because gypsum can dissolve, leaving voids. Expansive soils occur in some places along the alignment and are associated with clay deposits, primarily montmorillonite derived from basalts. If design considerations are implemented where appropriate, no significant impacts would occur associated with operations and maintenance activities.

4.4.2.5 Geologic Hazards to Human Health and Safety

No significant impacts would occur.

4.4.2.6 Important Structures and Mineral Resources

No significant impacts would occur.

4.4.2.7 Borrow and Spoil

No significant impacts would occur.

4.5 Southeast Corner Alternative

4.5.1 Construction Impacts

4.5.1.1 Fault Movement

Impacts would be the same as for the South Alternative. No impacts would occur during construction.

4.5.1.2 Seismic Activity

Impacts would be the same as for the South Alternative. No impacts would occur during construction.

4.5.1.3 Unstable Slopes

Impacts would be the same as for the South Alternative. No impacts would occur during construction.

4.5.1.4 Expandable, Collapsible, or Subsiding Soils or Rocks

Impacts would be the same as for the South Alternative. No impacts would occur during construction.

4.5.1.5 Geologic Hazards to Human Health and Safety

Impacts would be the same as for the South Alternative. No impacts would occur during construction.

4.5.1.6 Important Structures and Mineral Resources

Impacts would be the same as for the South Alternative. No impacts would occur during construction.

4.5.1.7 Borrow and Spoil

It is anticipated that most, if not all, material for the pipe zone and underlying bedding will be obtained from commercial sand and gravel pits. Some public pits have been identified and may be used, but these are not likely to be major sources of material. All borrow will be obtained from existing disturbed sites, either public or private. Therefore no significant impacts associated with obtaining borrow materials would occur.

Disposal of spoils is expected to be primarily, if not entirely, by spreading within the alignment right of way. This spreading will be in accordance with practices that would be reviewed and approved by the governing public agencies and Indian tribe, including BLM, NPS, Kaibab Band of Paiute Indians, UDOT and ADOT as well as on private lands. In most locations, less than one foot of spoils is anticipated to be spread across the alignment right of way. Where spreading is not allowed or is not sufficient to dispose of all spoils, materials will be deposited in existing, largely used-up gravel pits. All spoiled materials would be reclaimed by stabilization practices and seeding with an approved seed mix. Therefore no significant impacts associated with spoils would occur.

4.5.2 Operation and Maintenance Impacts

4.5.2.1 Fault Movement

Impacts would be the same as for the South Alternative. No impacts would occur during operations and maintenance.

4.5.2.2 Seismic Activity

Impacts would be the same as for the South Alternative. No impacts would occur during operations and maintenance.

4.5.2.3 Unstable Slopes

Impacts would be the same as for the South Alternative. No impacts would occur during operations and maintenance.

4.5.2.4 Expandable, Collapsible, or Subsiding Soils or Rocks

Impacts would be the same as for the South Alternative. No impacts would occur during operations and maintenance.

4.5.2.5 Geologic Hazards to Human Health and Safety

Impacts would be the same as for the South Alternative. No impacts would occur during operations and maintenance.

4.5.2.6 Important Structures and Mineral Resources

Impacts would be the same as for the South Alternative. No impacts would occur during operations and maintenance.

4.5.2.7 Borrow and Spoil

Impacts would be the same as for the South Alternative. No impacts would occur during operations and maintenance.

4.6 Cedar Valley Pipeline Alternative

4.6.1 Construction Impacts

4.6.1.1 Fault Movement

The relatively short duration of construction activities would not be long enough for fault movement, projected to be 0.6 mm/yr or less along the Hurricane fault system, to affect pipeline construction. Therefore no significant impacts associated with fault movement would occur.

4.6.1.2 Seismic Activity

The CVP Alternative alignment would lie parallel or near to the seismically active Hurricane fault system. However, the CVP Alternative alignment lies within a zone of low to moderate potential for PGA with a two-percent probability of exceedance over 50 years. The probability of a large earthquake event during construction is also relatively small. For these reasons, no significant impacts would occur.

4.6.1.3 Unstable Slopes

Locations where rockfall and steep slopes exist along the CVP Alternative alignment are shown in Table 3-16. Nine segments of pipeline were identified that are subject to rockfall hazards on steep slopes. These locations are primarily associated with adjacent loose rock outcrops on steep slopes. These locations may be subject to failure, particularly in the event of an earthquake. Individual locations would need to be examined before heavy earthwork, especially blasting, could take place, and site stabilization measures or removal of rock and soil at risk of failure may need to occur before proceeding. If these precautions are followed, no significant impacts would occur.

4.6.1.4 Expandable, Collapsible, or Subsiding Soils or Rocks

Some sections of the CVP Alternative alignment may be subject to expandable, collapsible, or subsiding soils or rocks, as identified in Table 3-18. These are primarily associated with gypsiferous soils, which are susceptible to subsidence if gypsum is extensively wetted because gypsum can dissolve, leaving voids. Expansive soils occur in some places along the alignment and are associated with clay deposits, primarily montmorillonite derived from basalts. Construction in such materials may require special design considerations, such as over excavation and placement of additional bedding, may be necessary. If design considerations are implemented where appropriate, no significant impacts would occur.

4.6.1.5 Geologic Hazards to Human Health and Safety

Geologic hazards to human health and safety would be minimized by following appropriate and site-specific precautions, including trench shoring or sloping, slope stabilization where applicable, and other standard construction safety practices. Therefore no significant impacts would occur.

4.6.1.6 Important Structures and Mineral Resources

Human structures within 1,000 feet of the CVP Alternative alignment are shown in Table 3-19. The primary risk of damage is associated with the effects of blasting during trenching, since none of the structures are in the direct alignment (excluding highway crossings, which are not included as part of this evaluation and in any event will be repaired as necessary). Structures or groups of structures that may be at risk from blasting include houses, manholes, pipes, wells, and other features; all other important structures are not near trench sections that would require blasting. Many of these features occur near pipes and manholes within the Nephi's Twist trail area; houses, manholes, and pipelines in the Toquerville area; and fire hydrants, pipelines, manholes, a gas pipeline, and building in the Pintura area. Special blasting methods may need to be employed to minimize the transfer of energy through rock and soil to the structures. Use of lower-energy blasting methods at closer spacings would minimize the effects of blasting near structures. Therefore no significant impacts would occur.

4.6.1.7 Borrow and Spoil

It is anticipated that most, if not all, material for the pipe zone and underlying bedding will be obtained from commercial sand and gravel pits. Some public pits have been identified and may be used, but these are not likely to be major sources of material. All borrow will be obtained from existing disturbed sites, either public or private. Therefore no significant impacts associated with obtaining borrow materials would occur.

Disposal of spoils is expected to be primarily, if not entirely, by spreading within the alignment right of way. This spreading will be in accordance with practices that would be reviewed and approved by the governing public agencies, including BLM and UDOT, as well as on private lands. In most locations, less than one foot of spoils is anticipated to be spread across the alignment right of way. Where spreading is not allowed or is not sufficient to dispose of all spoils, materials will be deposited in existing, largely used-up gravel pits. All spoiled materials would be reclaimed by stabilization practices and seeding with an approved seed mix. Therefore no significant impacts associated with spoils would occur.

4.6.2 Operation and Maintenance Impacts

4.6.2.1 Fault Movement

None of the faults along the CVP Alternative alignment are believed to have a displacement rate of more than about 0.6 mm/yr, and most faults are projected to have much lower average rates of displacement, if any at all, during the design life of the Project. A displacement of 0.6 mm/yr would result in a total displacement of 45 mm over the Project design life. Because the Hurricane Fault has been seismically active in recent history (the most recent major earthquake occurring in 1992 near St. George), there is a risk of substantial rapid fault movement and associated displacement within the Project design life. However, average rates of displacement have been between 0.12 and 0.6 mm/yr, meaning that fault displacement probably would be significant to pipeline rupture only if it represents release of stresses that have accumulated for about 125 years or more (for a 75 mm displacement). It is assumed that the 1992 earthquake event and other relatively recent earthquakes along the Hurricane Fault released at least some of the accumulated stresses in the vicinity of the pipeline crossing on the Hurricane Fault. Displacement rates, if known, on other major faults crossed by the CVP Alternative alignment are generally believed to be lower than displacement rates for most of the Hurricane Fault. Therefore no significant impacts associated with fault movement would occur.

4.6.2.2 Seismic Activity

The CVP Alternative alignment would lie parallel or near to the Hurricane fault system. The Hurricane fault system, including interrelated normal faults and grabens within a fault zone parallel to and just west of the Hurricane Cliffs, is considered to be seismically active and has demonstrated the potential for relatively large-magnitude quakes, including the 5.8 magnitude St. George earthquake in 1992. However, the CVP Alternative alignment lies within a zone of low to moderate potential for PGA with a two-percent probability of exceedance over 50 years. If proper consideration is given to using appropriate seismic design standards for pipelines and associated facilities, no significant impacts would occur.

Saturated sandy soils occur at the La Verkin Creek crossing, but the projected PGA risk is low to moderate, and proper design and construction would minimize the risks associated with liquefaction. Therefore no significant impacts would occur as a result of liquefaction.

4.6.2.3 Unstable Slopes

Locations where rockfall and steep slopes exist along the CVP Alternative alignment are shown in Table 3-16. No steep, unstable slopes were identified that would be likely to fail in a manner that would either be caused by, or cause damage to, the pipeline and associated facilities. Therefore no significant impacts would occur.

4.6.2.4 Expandable, Collapsible, or Subsiding Soils or Rocks

Impacts associated with expandable, collapsible, or subsiding soils or rocks would be similar to construction impacts, except that operations and maintenance would occur over a longer period of time and therefore the probability of soil or rock expansion, collapse, or subsidence in a manner that could affect the Project may be greater. However, if proper design and construction practices are followed, no significant impacts would occur.

Reduction of pumping of groundwater in the Cedar Valley would help to reduce the rate of land subsidence associated with over pumping of the aquifer, and may cause subsidence to halt. This would be a positive impact.

4.6.2.5 Geologic Hazards to Human Health and Safety

No significant impacts would occur.

4.6.2.6 Important Structures and Mineral Resources

No significant impacts would occur.

4.6.2.7 Borrow and Spoil

No significant impacts would occur.

4.7 No Lake Powell Water Alternative

4.7.1 WCWCD No Lake Powell Water Alternative

4.7.1.1 Fault Movement

No impacts would occur.

4.7.1.2 Seismic Activity

No impacts would occur.

4.7.1.3 Unstable Slopes

No impacts would occur.

4.7.1.4 Expandable, Collapsible, or Subsiding Soils or Rocks

No impacts would occur.

4.7.1.5 Geologic Hazards to Human Health and Safety

No impacts would occur.

4.7.1.6 Important Structures and Mineral Resources

No impacts would occur.

4.7.1.7 Borrow and Spoil

No impacts would occur.

4.7.2 CICWCD No Lake Powell Water Alternative

4.7.2.1 Fault Movement

No impacts would occur.

4.7.2.2 Seismic Activity

No impacts would occur.

4.7.2.3 Unstable Slopes

No impacts would occur.

4.7.2.4 Expandable, Collapsible, or Subsiding Soils or Rocks

Over pumping of groundwater in the Cedar Valley would continue to deplete the aquifer, which would result in continuation of land subsidence. This would not be a significant impact on the Project since there would be no pipeline or facilities to damage. However, the effect on land users could be significant if subsidence changes drainage patterns. Also, soil fissures caused by land subsidence already allow direct inflow of raw surface water into the ground and may provide a conduit for surface water to flow unfiltered into the aquifer. If this trend continues due to over pumping, it could have a significant impact on groundwater quality.

4.7.2.5 Geologic Hazards to Human Health and Safety

No impacts would occur.

4.7.2.6 Important Structures and Mineral Resources

No impacts would occur.

4.7.2.7 Borrow and Spoil

No impacts would occur.

4.7.3 KCWCD No Lake Powell Water Alternative

4.7.3.1 Fault Movement

No impacts would occur.

4.7.3.2 Seismic Activity

No impacts would occur.

4.7.3.3 Unstable Slopes

No impacts would occur.

4.7.3.4 Expandable, Collapsible, or Subsiding Soils or Rocks

No impacts would occur.

4.7.3.5 Geologic Hazards to Human Health and Safety

No impacts would occur.

4.7.3.6 Important Structures and Mineral Resources

No impacts would occur.

4.7.3.7 Borrow and Spoil

No impacts would occur.

4.8 No Action Alternative

4.8.1 WCWCD No Lake Powell Water Alternative

4.8.1.1 Fault Movement

No impacts would occur.

4.8.1.2 Seismic Activity

No impacts would occur.

4.8.1.3 Unstable Slopes

No impacts would occur.

4.8.1.4 Expandable, Collapsible, or Subsiding Soils or Rocks

No impacts would occur.

4.8.1.5 Geologic Hazards to Human Health and Safety

No impacts would occur.

4.8.1.6 Important Structures and Mineral Resources

No impacts would occur.

4.8.1.7 Borrow and Spoil

No impacts would occur.

4.8.2 CICWCD No Lake Powell Water Alternative

4.8.2.1 Fault Movement

No impacts would occur.

4.8.2.2 Seismic Activity

No impacts would occur.

4.8.2.3 Unstable Slopes

No impacts would occur.

4.8.2.4 Expandable, Collapsible, or Subsiding Soils or Rocks

Impacts would be the same as for the No Lake Powell Water Alternative.

4.8.2.5 Geologic Hazards to Human Health and Safety

No impacts would occur.

4.8.2.6 Important Structures and Mineral Resources

No impacts would occur.

4.8.2.7 Borrow and Spoil

No impacts would occur.

4.8.3 KCWCD No Lake Powell Water Alternative

4.8.3.1 Fault Movement

No impacts would occur.

4.8.3.2 Seismic Activity

No impacts would occur.

4.8.3.3 Unstable Slopes

No impacts would occur.

4.8.3.4 Expandable, Collapsible, or Subsiding Soils or Rocks

No impacts would occur.

4.8.3.5 Geologic Hazards to Human Health and Safety

No impacts would occur.

4.8.3.6 Important Structures and Mineral Resources

No impacts would occur.

4.8.3.7 Borrow and Spoil

No impacts would occur.

Chapter 5
Mitigation and Monitoring

5.1 South Alternative

5.1.1 Mitigation

No mitigation of impacts would be required if Best Management Practices are followed and design and construction activities include consideration of risks identified.

5.1.2 Monitoring

No monitoring would be required.

5.2 Existing Highway Pipeline Alternative

5.2.1 Mitigation

No mitigation of impacts would be required if Best Management Practices are followed and design and construction activities include consideration of risks identified.

5.2.2 Monitoring

No monitoring would be required.

5.3 Southeast Corner Alternative

5.3.1 Mitigation

No mitigation of impacts would be required if Best Management Practices are followed and design and construction activities include consideration of risks identified.

5.3.2 Monitoring

No monitoring would be required.

5.4 Cedar Valley Pipeline Alternative

5.4.1 Mitigation

No mitigation of impacts would be required if Best Management Practices are followed and design and construction activities include consideration of risks identified.

5.4.2 Monitoring

No monitoring would be required.

5.5 No Lake Powell Water Alternative

5.5.1 Mitigation

Alternative water supplies, combined with extensive water conservation measures, would be necessary to mitigate for increased demands from growth.

Subsidence resulting from over pumping of groundwater in the Cedar Valley would require regular repairs of broken or damaged structures, including roads, buildings, or other structures in the direct alignment of soil fissures. Damage to pipelines and reversal of gravity flow may require redesign and replacement of pipelines and possibly installation of pump stations and associated power requirements.

5.4.2 Monitoring

Monitoring of subsidence in affected areas may be required, including periodic land elevation surveys in developed areas where evidence of subsidence occurs.

5.6 No Action Alternative

5.6.1 Mitigation

Alternative water supplies, combined with extensive water conservation measures, would be necessary to mitigate for increased demands from growth.

Subsidence resulting from over pumping of groundwater in the Cedar Valley would require regular repairs of broken or damaged structures, including roads, buildings, or other structures in the direct alignment of soil fissures. Damage to pipelines and reversal of gravity flow may require redesign and replacement of pipelines and possibly installation of pump stations and associated power requirements.

5.6.2 Monitoring

Monitoring of subsidence in affected areas may be required, including periodic land elevation surveys in developed areas where evidence of subsidence occurs.

Chapter 6
Unavoidable Adverse Impacts

6.1 South Alternative

No unavoidable adverse impacts associated would occur.

6.2 Existing Highway Pipeline Alternative

No unavoidable adverse impacts would occur.

6.3 Southeast Corner Line Alternative

No unavoidable adverse impacts would occur.

6.4 Cedar Valley Pipeline Alternative

No unavoidable adverse impacts would occur.

6.5 No Lake Powell Water Alternative

Continued subsidence of land levels, with associated damage to property and structures, would occur in portions of the Cedar Valley.

6.6 No Action Alternative

Continued subsidence of land levels, with associated damage to property and structures, would occur in portions of the Cedar Valley.

Chapter 7
Cumulative Impacts

This chapter analyzes cumulative impacts that may occur from construction and operation of the proposed LPP project when combined with the impacts of other past, present, and reasonably foreseeable future actions and projects after all proposed mitigation measures have been implemented. Only those resources with the potential to cause cumulative impacts are analyzed in this chapter.

7.1 South Alternative

(The cumulative impacts analysis is pending completion for identification of inter-related projects that would cause cumulative impacts with the LPP project.)

7.2 Existing Highway Alternative

(The cumulative impacts analysis is pending completion for identification of inter-related projects that would cause cumulative impacts with the LPP project.)

7.3 Southeast Corner Alternative

(The cumulative impacts analysis is pending completion for identification of inter-related projects that would cause cumulative impacts with the LPP project.)

7.4 Transmission Line Alternatives

(The cumulative impacts analysis is pending completion for identification of inter-related projects that would cause cumulative impacts with the LPP project.)

7.5 No Lake Powell Water Alternative

(The cumulative impacts analysis is pending completion for identification of inter-related projects that would cause cumulative impacts with the LPP project.)

7.6 No Action Alternative

The No Action Alternative would have no cumulative impacts.

References

American Society for Testing and Materials (ASTM). 2000. ASTM D 2488-00, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure).

__________. 2006. ASTM D 2487-06, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System).

Arizona Bureau of Mines (ABM). 1959. Geologic map of Mohave County, Arizona: Arizona Bureau of Mines and University of Arizona, Scale 1:375,000. Prepared by E.D. Wilson and R.T. Moore.

__________. 1960. Geologic map of Coconino County, Arizona: University of Arizona, Arizona Bureau of Mines, 1:375,000. Prepared by R.T. Moore, E.D. Wilson, and R.T. O'Haire.

Fugro William Lettuce and Associates. (FWLA) 2009. Geologic Characterization of Multiple Fault Crossings along the Proposed Lake Powell and Cedar Valley Pipelines, Hurricane Cliffs Hydropower Facility, Iron, Washington and Kane Counties, Utah and Mohave and Coconino Counties, Arizona.

Hoek E., Marinos P., Benissi M., Applicability of the geological strength index (GSI) classification for very weak and sheared rock masses. The case of the Athens Schist Formation, Bull. Eng. Geol. Env., 57, 151-160, 1998.

MWH Americas (MWH). 2009a. Lake Powell Pipeline Phase I – Preliminary Engineering and Environmental Studies, Task 5 – Develop and Analyze Alternatives, Technical Memorandum 5.11 - Geological, Geotechnical and Foundation Conditions.

__________. 2009b. Lake Powell Pipeline Phase II – Preliminary Engineering and Environmental Studies, Task 6 – Conceptual Design Report.

__________. 2009c. Lake Powell Pipeline Phase II – Preliminary Engineering and Environmental Studies, Task 6 – Conceptual Design Report, Appendix B – Special Crossings Details. Utah Geological Survey (UGS). 1995a. Geologic map of the Hildale quadrangle, Washington and Kane Counties, Utah and Mojave County, Arizona: Utah Geological Survey Map 167. Prepared by E.G. Sable.

__________. 2010. Groundwater Resources Technical Report.

Natural Resources Conservation Service (NRCS). 1971. Soil survey of Washington County area, Utah.

__________. 1983. Soil survey of Coconino County area, Arizona, North Kaibab Part.

__________. 1996. Soil survey of Iron-Washington area, parts of Iron, Kane, and Washington Counties.

__________. 2003. Soil survey of Grand Staircase-Escalante National Monument area, parts of Kane and Garfield Counties, Utah.

__________. 2007a. Soil survey of Coconino County area, Arizona, north Kaibab part: Web-soil survey maps. http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx.

__________. 2007b. Soil survey of Grand Staircase-Escalante National Monument area, parts of Kane and Garfield Counties, Utah. Web-soil survey soils maps. http://websoilsurvey.nrcs. usda.gov/app/WebSoilSurvey.aspx.

__________. 2007c. Soil survey of Iron-Washington area, parts of Iron, Kane, and Washington Counties: Web-soil survey maps. http://websoilsurvey.nrcs.usda.gov/app/ WebSoilSurvey.aspx.

__________. 2007d. Soil survey of Washington County area, Utah: Web-soil survey maps. http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx.

U.S. Geological Survey (USGS). 1963. Geology of the Lees Ferry area, Coconino County, Arizona: U.S. Geological Survey Bulletin 1137. Prepared by D.A. Phoenix.

__________. 2004a. Geologic map of the Kanab 30' x 60' quadrangle, Utah and Arizona: U.S. Geological Survey Geologic Investigations Series I-2655. Prepared by E.G. Sable and R. Herford.

__________. 2004b. Geologic map of the Pipe Spring National Monument and the western Kaibab-Paiute Reservation, Mohave County, Arizona: U.S. Geological Survey Scientific Investigations Map 2863. Prepared by G.H. Billingsley, S.S. Priest, and T. Felger.

__________. 2009. Hazard Mapping Images and Data: USGS National Seismic Hazard Maps, Data, and Documentation.

Utah Board of Water Resources (UBWR). 2008. Lake Powell Hydroelectric System, Revised Study Plan 4: Geology and Soils. Federal Energy Regulatory Commission Project No. 12966. Prepared by the Utah Division of Water Resources.

Utah Division of Water Resources (UDWR). 2007. Draft municipal and industrial water supply and uses in the Cedar/Beaver Basin (Data collected for the year 2005). November 2007.

Utah Division of Water Resources (UDWR). 2009. *Municipal and industrial water supply and uses in the Kanab Creek/Virgin River Basin (data collected for the year 2005)*. January 2009.

__________. 2011. *Water Needs Assessment, Draft, Lake Powell Pipeline.* Prepared by MWH, Inc. March 2011.

Utah Geological and Mineral Survey (UGMS). 1989. Geology of Kane County, Utah – Geologic Hazard Map. Bulletin 124. Prepared by H.H. Doelling, and D.D. Fitzhugh.

Utah Geological Survey (UGS). 1995a. Geologic map of the Hildale quadrangle, Washington and Kane Counties, Utah and Mojave County, Arizona: Utah Geological Survey Map 167. Prepared by E.G. Sable.

__________. 1995b. Geologic map of the New Harmony Quadrangle, Washington County, Utah: Utah Geological Survey Miscellaneous Publications 95-2. Prepared by S.K. Grant.

__________. 1999. Digital geologic map of the Kanab 30' x 60' quadrangle, Kane and Washington Counties, Utah and Coconino County, Arizona: Utah Geological Survey Open-File Report 366. Prepared by H.H. Doelling.

__________. 2001. Geologic map of the Smithsonian Butte quadrangle, Washington County, Utah: Utah Geological Survey Miscellaneous Publication 01-1. Prepared by D.W. Moore and E.G. Sable.

__________. 2003a. Geologic map of the Harrisburg Junction 7.5' quadrangle, Washington County, Utah: Utah Geological Survey Map 191. Prepared by R.F. Biek.

__________. 2003b. Geologic map of the Hurricane 7.5' quadrangle, Washington County, Utah: Utah Geological Survey Map 187. Prepared by R.F. Biek.

__________. 2003c. Geologic map of the Pintura quadrangle, Washington County, Utah: Utah Geological Survey Map 196. Prepared by H.A. Hurlow and R.F. Biek.

__________. 2004a. Geologic map of the Divide quadrangle, Washington County, Utah: Utah Geological Survey Map 197. Prepared by J.M. Hayden.

__________. 2004b. Geologic map of the Little Creek Mountain quadrangle, Washington County, Utah: Utah Geological Survey Map 204. Prepared by J.M. Hayden.

__________. 2005. Geologic Map of the Washington Dome Quadrangle, Washington County, Utah: Utah Geological Survey Map 209. Prepared by J.M. Hayden.

__________. 2006a. Geologic map of the Smoky Mountain 30' x 60' quadrangle, Kane and San Juan Counties, Utah, and Coconino County, Arizona: Utah Geological Survey Map 213. Prepared by H.H. Doelling and G.C. Willis.

__________. 2006b. Interim geologic map of the Cedar City 30' x 60' quadrangle, Iron and Washington Counties, Utah: Utah Geological Survey Open-File Report 476DM. Prepared by P.D. Rowley, V.S. Williams, G.S. Vice, D.J. Maxwell, D.B. Hacker, L.W. Snee, and J.H. Mackin.

__________. 2007. Interim Geologic Map of the St. George 30' x 60' Quadrangle and the east part of the Clover Mountain 30' x 60' Quadrangle, Washington and Iron Counties, Utah: Utah Geological Survey Open-File Report 478. Prepared by R.F. Biek, P.D. Rowley, D.B. Hacker, J.M. Hayden, G.C. Willis, L.F. Hintze, R.E. Anderson, and K.D. Brown.

__________. 2008a. Collapsible-Soil-Susceptibility Map for the St. George-Hurricane Metropolitan Area. Special Study 127. Plate 7. Prepared by W.R. Lund, T.R. Kundsen, G.S. Vice, and L.M. Shaw.

__________. 2008b. Expansive-Soil-and Rock-Susceptibility Map for the St. George-Hurricane Metropolitan Area. Special Study 127. Plate 6. Prepared by W.R. Lund, T.R. Kundsen, G.S. Vice, and L.M. Shaw.

__________. 2008c. Gypsiferous-Soil-and Rock-Susceptibility Map for the St. George-Hurricane Metropolitan Area. Special Study 127. Plate 8. Prepared by W.R. Lund, T.R. Kundsen, G.S. Vice, and L.M. Shaw.

__________. 2008d. Landslide-Hazard Map for the St. George-Hurricane Metropolitan Area. Special Study 127. Plate 4. Prepared by W.R. Lund, T.R. Kundsen, G.S. Vice, and L.M. Shaw.

__________. 2008e. Shallow-Bedrock-Susceptibility Map for the St. George-Hurricane Metropolitan Area. Special Study 127. Plate 10. Prepared by W.R. Lund, T.R. Kundsen, G.S. Vice, and L.M. Shaw.

__________. 2008f. Surface-Fault-Rupture-Hazard Map for the St. George-Hurricane Metropolitan Area. Special Study 127. Plate 1. Prepared by W.R. Lund, T.R. Kundsen, G.S. Vice, and L.M. Shaw.

__________. 2009. Presentation regarding the Enoch earth fissure. Presented to the Central Iron County Water Conservancy District, June 11, 2009. Presented by W.R. Lund.

US Department of the Interior Bureau of Reclamation (USBR). 1998. Engineering Geology Field Manual, Second Edition.

Washington County Water Conservancy District (WCWCD). 2005. Geology along the route of the Lake Powell water pipeline, Utah and Arizona: Washington County Water Conservancy District Report WCWCD-02. Prepared by P.D. Rowley, G.L. Dixon, and D.W. Brickey, February 2005.

Glossary

Alluvium. A deposit of soil particles transported by flowing water.

Borrow. Excavated material that is removed from one location, such as a pit, and used as foundation material, bedding, or backfill at another location to facilitate construction.

Collapsible Soil. A loosely deposited soil that collapses into a denser, more compact soil, usually after saturation. Collapsible soils typically include porous alluvial fans and windblown soil deposits.

Expansive Soil. A type of clay that absorbs and retains moisture between platy particles, causing the particles to be pushed apart and resulting in an increase in occupied soil volume. Over time, the clay may dry out from drainage or evaporation, and the resulting contraction of soil particles causes cracking and desiccation.

Fault. A plane of displacement caused by one part of the earth's crust relative to the adjacent part. A normal fault is a fault where the downthrown side moves on a plane dipping at less than 180 degrees. A reverse fault is a fault where the downthrown side moves on a plane dipping at greater than 180 degrees.

Graben. A geologic feature caused by two adjacent, parallel faults which result in a downward movement of a block of the earth's crust between the faults.

Holocene Epoch. A unit of geologic time corresponding to the period from approximately the end of the last Ice Age until the present time, roughly 10,000 years.

Liquefaction. Process whereby granular, saturated or wet soils change from a solid state to a liquid state as a result of loading, most often caused by an infusion of energy acceleration associated with an earthquake.

Loess. A windblown soil deposit. Loess deposits tend to be loosely deposited and are often subject to collapse when extensively saturated.

Quaternary Period. A unit of geologic time corresponding to the period at about the beginning of the last Ice Age until the present time, roughly 1.8 million years, and inclusive of the Pleistocene and Holocene Epochs.

Seismic Activity. An earthquake that releases energy as opposing sides of a fault move against each other, resulting in propagation of energy waves through rock and soil.

Spoil. Excess excavated material that is not suitable for foundations, bedding, or backfill and must be disposed of.

Subsidence. Lowering of a part of the land surface as a result of compaction of underlying soils, usually caused by either dissolving of materials within the soil or by removal of groundwater and the associated reduction in pressures within the soil pores.

Abbreviations and Acronyms

ABM	Arizona Bureau of Mines
ASTM	American Society for Testing and Materials
BEGE	
BLM	U.S. Department of the Interior, Bureau of Land Management
BMP	Best Management Practices
BPS	Booster Pump Station
CBPS	Cedar Valley Pipeline Booster Pump Station
CFR	Code of Federal Regulations
CICWCD	Central Iron County Water Conservancy District
CVP	Cedar Valley Pipeline
FERC	Federal Energy Regulatory Commission
FWLA	Fugro, Williams, Lettice and Associates
GOPB	Utah Governor's Office of Planning and Budget
gpcd	Gallons per capita day
GSENM	Grand Staircase-Escalante National Monument
HS	Hydropower Station
HWY	Highway
Hydro	Hydropower
KCWCD	Kane County Water Conservancy District
kV	kilovolt
LPP	Lake Powell Pipeline
Ma	Million years ago
M&I	Municipal and Industrial
MSL	Mean Sea Level (feet above)
NPS	U.S. Department of the Interior, National Park Service
NRCS	U.S. Department of Agriculture, Natural Resource Conservation Service
O&M	Operations and Maintenance
OSHA	Occupational Safety and Health Administration
PGA	Peak Ground Acceleration
Project	Lake Powell Pipeline Project
RO	Reverse Osmosis
SITLA	Utah School and Institutional Trust Lands Administration
Study Plan	FERC Geology and Soils Study Plan
TDS	Total Dissolved Solids
UBWR	Utah Board of Water Resources
UDWR	Utah Department of Water Resources
USCS	Unified Soil Classification System
UGS	Utah Geological Survey
UGMS	Geological and Mineralogical Survey (now UGS)
USBR	U.S. Department of the Interior, Bureau of Reclamation
USGS	U.S. Department of the Interior, Geological Survey
WCS	Water Conveyance System
WCWCD	Washington County Water Conservancy District

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Appendices

Appendix A – FWLA Report